D. SAFETY ASSESSMENT

1. Policies and Procedures

a. Range Safety Responsibility - This responsibility rests with the WSMC Commander in accordance with Department of Defense Directive 3200.11. The specific document which defines safety requirements to be met by a Range User is WSMC Regulation 127-1, "Range Safety Regulation". This document describes safety policies, and also defines data submittal and launch preparation safety criteria to be met by Range Users. Categories addressed in the regulation include flightanalysis, ground safety, flight termination systems, ground operations and flight operations.

Range Safety usually participates in preliminary conceptual discussions with the potential Range User. Such meetings are normally followed by specific inquiries requesting clarification of various WSMC Range Safety criteria. Following these contacts, the Range User must comply with WSMC documentation submittal requirements.

b. Hazardous Operating Procedures - All hazardous operations conducted on the Range are covered by hazardous operating procedures which have been reviewed and approved by Range Safety. In addition, all procedures for installation and checkout of the Flight Termination System require review and approval by Range Safety. Operations using these procedures are monitored by Range Safety personnel who have the authority to terminate any operation for safety violations. This applies from the time the launch vehicle arrives on the Range until it is launched.

c. FTS Requirements - All activities associated with the design, development, testing, installation and checkout of the FTS are closely monitored by Range Safety. WSMCR 127-1 specifies design and testing requirements of the FTS. Design requirements cover such details as receiver sensitivity, operating bandwidth, required number of decoder channels and destruct logic. Testing requirements include qualification and acceptance testing of FTS components, system testing after the components are assembled and confidence testing which is performed during vehicle buildup and launch preparations. The Range User responds to these requirements by publishing a Flight Termination System Report, which contains required information, and by submitting it to Range Safety for review and approval.

(1) Testing - FTS testing is normally done by the vendor or the Range User using test procedures approved by Range Safety. Qualification tests are functional tests that are run on each component during and after exposure to the environmental extremes that the component will experience during flight, and is probably the most important series of tests that is conducted on each component. Once qualification tests have been completed satisfactorily, the component is accepted by Range Safety to fly on the Range. This acceptance holds true until the component either fails in some way or is modified. Then, a failure analysis, with recommended corrective action, or proposed modification design data is submitted to Range Safety for approval. The component might have to be re-qualified, depending upon the type of failure or the

extent of the modification. Acceptance Tests are normally run at the vendor's facility on each FTS component. In addition, "bench tests" are conducted by the WSMC just prior to installation on the vehicle. Final acceptance of the system on each launch vehicle is not acknowledged until Range Safety gives the clearance to launch in the last few minutes of the launch countdown.[3]

(2) Testing Effectiveness - Design and testing requirements for the FTS are levied on the Range User to assure proper system integrity. These design and testing requirements have resulted in the probability of total FTS failure for a redundant system being $<6 \times 10^{-4}$ (a conservative estimate based on an assumption of a failure on the next or subsequent flight). See FTS Reliability, page 73.

d. Safety Waivers - The WSMC/SE policy is to avoid using waivers except in extremely rare situations; however, a waiver may be granted if the mission objectives are considered of sufficient importance to justify the added risks. A formal request for a waiver must include an analysis of the added risks and a justification, both supported by technical studies. Costs alone are insufficient justification.

2. Safety Organization - The WSMC safety office is responsible for establishing and monitoring the Commander's Missile Ground Safety Program at WSMC facilities on VAFB and all other WSMC locations. The WSMC Safety organization is shown in **Figure 14**[4]. The WSMC Commander has final authority and responsibility for missile flight safety from launch through impact or orbital insertion. During countdown and flight, the Range Safety Officer (RSO) is responsible for flight safety operations as the direct representative of the WSMC Commander. Within the safety organization, there are four divisions:

a. Flight Analysis Division (WSMC/SEY) - This division approves flight plans and establishes criteria for flight termination action in conjunction with risk assessments. Establishes requirements for and reviews submissions of Range Users to support flight safety functions.

b. Missile Flight Control Division (WSMC/SEO) - This division has the responsibility for carrying out launch vehicle flight safety. This extends from launch to impact for sub-orbital vehicles and from launch to orbital insertion or escape velocity for space vehicles. During launch operations, the RSO acts for the WSMC Commander on all flight safety matters. Establishes missile-borne flight termination and tracking systems design, operational performance, testing and data requirements. The Flight Safety Project Officer (FSPO) conducts engineering analyses and evaluations
for new or modified flight termination systems and approves their use at the WSMC.

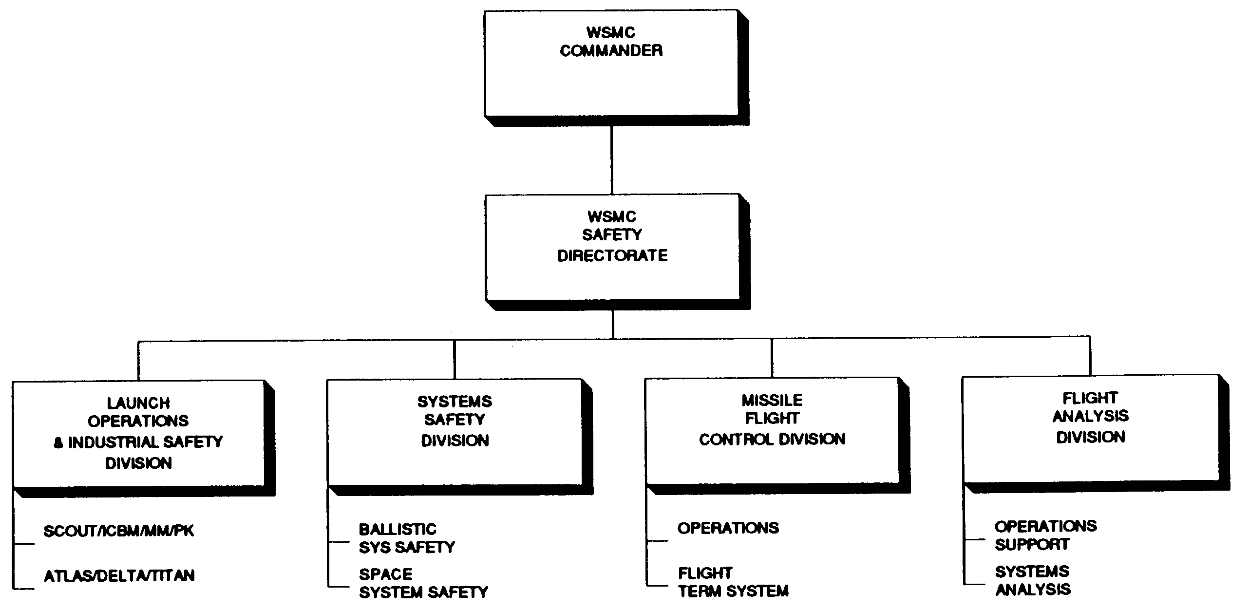

FIGURE 14. WESTERN SPACE AND MISSILE CENTER SAFETY ORGANIZATION

c. Launch Operations/Industrial Safety Division (WSMC/SEM) - This division is responsible for providing missile systems, ground, industrial and explosive safety program management support. Reviews hazardous procedures and operations and provides missile system ground safety management during launch operations as a member of the launch team for WSMC launches.

d. Missile Systems Safety Division (WSMC/SES) - This division establishes criteria and develops policies and controls to protect life and equipment. They evaluate and analyze potentially hazardous systems and implement/manage the system safety program. They have the responsibility for providing Missile System Ground Safety Approvals.[4]

3. Range Safety Personnel Training

a. Range Safety Officer

(1) Background Requirements - The desired background requirements for a Range Safety Officer are:

(a) Grade - Must be an Air Force Officer, preferably a Captain or above or a civilian, GS-9 or above. However, an officer of the rank of First Lieutenant would be considered if his experience or background is exceptional. Military personnel are usually assigned for approximately four years and then transferred.

(b) Education - Must have a bachelor's degree, preferably a master's degree, in some field of engineering.

(c) Experience - Experience in missile, space or aircraft operations is desired but not mandatory.

(2) General - The RSO Training and Certification program in place at the WSMC has the ultimate objective of providing the highest qualified individuals to support the Missile Flight Control effort. The secondary objective is to have each RSO fully qualified on each missile system. There are four types of RSO training: 1) Initial training for newly assigned personnel, 2) cross-training for initially certified RSO's, 3) Senior RSO training and 4) recurring and proficiency training for all Branch and supplemental support personnel. All newly assigned personnel undergo an initial training program leading to initial certification as a qualified RSO, and RSO's cross-train into additional missile programs. Experienced RSO's may be trained and certified as Senior RSO's. Recurring and proficiency training is a continuous program for all personnel. Each trainee is expected to exercise maximum initiative to complete all training items in the minimum time, consistent with launch opportunities and training priorities as established by the Training Officer (TO) and the Chief of the Missile Flight Control Operations Branch.

One RSO within the Missile Flight Control Division, Missile Flight Control Operations Branch (SEOO) (generally the most experienced RSO) will be assigned the duty of Training Officer (TO). Some of the specific responsibilities include:

- Monitor the progress of all trainees during their initial certification and during later cross-training.
- Perform all assignment scheduling for operational support. The primary goal is to achieve a well rounded capability among all RSO's and to accomplish new RSO certification as rapidly as possible.
- Schedule briefings, tours and courses for new trainees and the cross-training RSO's.
- Schedule and conduct the operational simulation training in the Missile Flight Control Center (MFCC).
- Schedule, coordinate and conduct recurring training sessions (as applicable).
- Present introductory briefings to incoming personnel and outline the training plan.
- Annually review the training Operating Instruction (OI).

The trainee is responsible for completing the assigned training items in the minimum time possible and for maintaining a record of the training accomplished.

(3) Training Plans/Certification - Training guidelines have been developed to assure that candidate RSO's are properly trained. These plans are divided into phases which define the basic requirements to be met by the trainee. His performance during this period is assessed by the Missile Flight Control Division Training Officer, who must recommend him for certification or for further training. The Director of Safety is the authority for providing initial RSO certification. The WSMC Commander is the sole authority for providing senior RSO certification. The following information is provided to identify the subject matter presented to the trainee during the various stages of his training program:

(a) Orientation Training - The orientation phase of training is primarily an indoctrination period. As soon as an individual is assigned to Missile Flight Control (MFC), the training officer (TO) will schedule the individual to observe one launch in the MFCC. This introduction will serve as general familiarization and a future reference point for additional training.

The TO will present an orientation briefing on the following agencies which will include general responsibilities relating to flight safety: Missile Flight Control Division (SEO), Flight Analysis Division (SEY), Pad and Industrial Safety Division (SEM) and Systems Safety Division (SES).

(b) Support Position Training - During the support position phase of training, the RSO trainee begins checkout and certification in the Missile Flight Control operational support positions. The positions are Back Azimuth and Program Outside Observer (OO) and Telemetry Observer (TM). These positions are frequently filled by supplemental support personnel.

[1] Skyscreen Training - The TO will schedule the trainee to

support both program and back azimuth Skyscreen positions. The trainee will support a minimum of 4 operations. He must first observe a mission operation by an experienced skyscreen operator and then, under supervision, call the next 3 launches. After the last supervised call, the trainee may be Skyscreen certified by the TO.

During this phase of training, the TO will show the trainee recorded mission films which will acquaint him with the appearance, from Skyscreen locations, of both nominal and non-nominal flights of various missiles.

[2] Telemetry Training - After Skyscreen certification, the trainee will begin operational telemetry support. The TO will provide telemetry training and the trainee will be supervised while performing telemetry support on a minimum of 3 launches. After the last call, the trainee may be telemetry certified by the TO.

During this phase of training, the TO will brief each trainee on the fundamentals of telemetry operations to include observing past telemetry tapes or printouts.

[3] Division Briefings - During this phase of training, a moredetailed briefing of SEY and SEO is presented to the trainee. Information provided includes: Missile Flight Control philosophy and procedures, personnel supporting RSO, equipment supporting RSO, impact limit lines, abort lines, debris patterns, ballistic coefficients, casualty expectancy, probability of impact, caution and hazards corridors, instantaneous impact prediction and the various computer systems/programs used by the Missile Flight Control Division.

[4] Tours - The TO schedules each trainee for tours to the radars, command transmitter sites, launch facilities, and flight termination systems support positions (consoles, etc.).

(c) RSO Console Training - The trainee is assigned to conduct a vehicle launch countdown, prepare documentation and attend or conduct operational meetings under the supervision of a qualified RSO. During this phase, the TO directs the trainee to spend time working directly with other elements of the Missile Flight Control Division and with organizations outside of SEO. The trainee will conduct vehicle countdown operations up to transmission of "safety green" (Range Safety clear to launch) to the Range.

• The trainee conducts a minimum of 4 launch countdowns. Also, during this time, each trainee undergoes simulated launch exercises. When this has been completed, the trainee is evaluated while acting as RSO on one launch. Upon successful completion of the checkout launch, the trainee may be certified for the RSO position by the Director of Safety upon recommendation of the Training Officer.

- Further briefings by SEY during this phase include a more detailed view of the analytical preparations necessary for each launch. Specifically, they include: documentation data submitted by the launch agency, initial flight plan approval, launch data letter, hazard analysis, LARA, Speed Plot (SPDPLT), decision models, launch, mid-range and terminal area hazards and warning messages.

Briefings by the Center Technical Service Contractor (CTSC) on their support functions are also given. The trainee follows a specific operation from start of task to launch. Ideally, this operation will be the trainee's certification launch.

The operations control manager briefs the trainee on the operational CTSC organizational positions. These include the OCS, RTDC, ROC, CTC, DNM and DAC.

The TO will schedule the trainee to tour as many launch facilities as possible.

(d) Training Timetable - The amount of time required for an RSO to complete his training and become certified is approximately one year from the time he begins the training program. However, this could be influenced by the individual's capabilities and the launch schedule.

(e) Cross-Training - RSO's begin cross-training on other missile systems as determined by the TO and SEOO Branch Chief. Checkout and certification procedures are identical to those outlined above. Upon certification, the new RSO is usuallyqualified on only one missile system. The TO will schedule the individual for training on different systems as they are scheduled by the Range. For missile type qualification, each RSO must conduct at least one countdown to "range green", see several non-nominal flight simulations and perform one supervised launch.

For each missile type, the RSO is briefed by the launch agency on vehicle characteristics and by the Flight Safety Project Officer (FSPO) on peculiar destruct equipment. The RSO is also briefed on new/modified destruct criteria.

(f) Proficiency Training - Proficiency training is a continuing program designed to maintain and enhance the skills of qualified RSO's. Methods used include: cross-talk sessions, where RSO's discuss problems encountered during actual launches and "what if" situations; briefings, where personnel introduce or update knowledge of new or continuing programs; and simulator training.

(g) Currency - All Missile Flight Control support positions manned by SE personnel have currency requirements which must be met semiannually and/or annually. Loss of currency will necessitate that the delinquent item/s or support be accomplished under the supervision of the TO before currency can be regained. These requirements are:

- An RSO must support one launch semiannually as an RSO. On a calendar year basis, one launch must be a ballistic vehicle and one launch must be an orbital vehicle.

- A Senior RSO must support one launch as Senior RSO semiannually.
- A Telemetry Observer must support one launch as TM per calendar year.
- An Outside Observer must support one launch as either Back Azimuth or Program per calendar year.

b. Senior RSO - The Senior RSO training phase begins when the RSO has achieved the prerequisites and demonstrated the skills specified above. The trainee must have been a certified RSO for at least one year. Additionally, the RSO must be certified on at least one ballistic and one space vehicle. Each individual must thoroughly understand the capability and limitations of each instrumentation system. He must recognize the inter-relationship between sensors and know what combinations for particular missiles constitute acceptable/unacceptable flight safety support.

(1) Trainee Knowledge - The SRSO trainee must understand the processes used to estimate train intervals and monitor their progress. The trainee must understand how to determine no-launch areas and when to call a hold for a train that is expected to be in a hazardous area. He must understand the procedures for monitoring a train whose entry into a no-launch area is estimated to be very close to T-0 when the launch window is very short. Similar understanding is required for ship/boat management, but he should also know how to estimate qualitative ship/boat hazards based on wind speed and direction. Most importantly, the trainee must understand the capabilities at the disposal of the Duty Air Controller (DAC).

The trainee must also be able to present safety policy and requirements during negotiations or discussions with other organizations.

(2) Certification Process - The SRSO trainee must participate in flight simulations involving indeterminate or nonexistent data. He is evaluated by the TO during the simulations and on one checkoUt flight operation. After successfully completing an oral exam given by the TO and the Director of Safety, the SRSO trainee may be recommended for certification by the WSMC Commander.[22]

c. Flight Safety Engineering Analyst (FSEA) - The Flight Analysis Division (SEY) training requirements for a new Flight Safety Engineering Analyst (FSEA) are general in nature and cover a broad range of various disciplines involved in missile flight safety. The following information outlines the required training for a new safety analyst to become a fully qualified FSEA:

(1) Documentation - The trainee shall become familiar with the following documents through reading and supervised discussions with senior FSEA's:

(a) DODD 3200.11
(b) WSMC Missile Flight Control Requirements
(c) WSMCR 127-1, Range Safety Requirements Manual
(d) WSMC Range Safety Officers Handbook

(e) SE Operating Instruction 127 Series
(f) SEY Operating Instruction Series
(g) WSMC Landbased Instrumentation Handbook
(h) WSMC Capability Summary Handbook
(i) Real-Time Debris Patterns for Ballistic Missile Launches
(j) RCC - Risk Analysis Techniques, RSG Document 315-79
(k) Agreements with Army, Navy, FAA, other Air Force units and oil companies
(l) Sample Environmental Impact Statements (EIS)
(m) Federal Register on Restricted Areas, Danger Zones and Warning Areas
(n) NOTAMS, HYDROPACS, LONOTES, CASPERS and (CINCPACFLT Instruction 3130.6E, 07 November 1983)

(2) Facilities Tours - The trainee is provided with supervised tours of the following facilities:

(a) Missile Flight Control Center
(b) CTSC Safety Group Area
(c) CYBER 840/860 (2) Computers
(d) Automatic Plotting Equipment Area
(e) Telemetry Centers (Bldg 7000)
(f) WECO Guidance Station
(g) Selected Launch Pads
(h) Selected Radar Sites
(i) Selected Command Transmitters
(j) Range Operations Control Center

(3) Off- Site Orientation - The trainee is given orientations on the following off-site locations. Visits are arranged when practical:

(a) Kwajalein
(b) ESMC
(c) PMTC
(d) Eglin AFB

(4) Familiarization Briefings - The trainee is provided briefings concerning the following:

(a) SAMTO/WSMC/SE organizational structure
(b) Missile flight safety functions, policy and criteria
(c) Typical missile flight safety system
(d) Flight safety display systems
(e) Real-Time support computer programs
(f) Flight safety production computer programs
(g) LARA computer program
(h) Caution and Hazard Corridors
(i) Saber computer programs
(j) West Coast Offshore Operating Area

(5) Indoctrination - The trainee is required to perform the following:

(a) Witness live launches from the safety center
(b) Witness trajectory simulations

(c) Monitor missile flight safety display checks
(d) Monitor Skyscreen operation during launch
(e) Participate in the development of two complete missile flight control data packages

(6) General Procedures in Operational Support - The trainee must familiarize himself with the following procedures:

(a) Range Users and Contractor Relations
(b) Formats
(c) Data Handling, Logging, Distribution and Checking
(d) Launch Scheduling
(e) Operations Support Tasks

(7) Missile Flight Safety Displays - The trainee must be familiar with the following:

(a) Basic Types of Displays
(b) Present Position Displays
(c) Vertical Plane Displays
(d) Velocity Displays
(e) Impact Prediction Displays
(f) Debris Pattern Displays
(g) Telemetry Displays

(8) Center Technical Services Contractor (CTSC) -The trainee shall become familiar with the following aspects of the CTSC:

(a) CTSC Flight Safety
(b) Flight Safety Support Functions
(c) Operation Support Concepts
(d) Future Flight Safety Systems

(9) Task Assignment Training - Each trainee is assigned certain tasks to perform during his training period. The following provides a list of the major areas covered:

(a) Trajectory Analysis
(b) Safety Analyst Support
(c) Hazard Analysis

(10) Mission Planning - The trainee becomes involved with the following aspects of mission planning:

(a) Evaluate mission scenarios
(b) Issue hazardous areas safety warning messages
(c) Issue flight plan approvals
(d) Issue launch approvals

(11) Training Timetable - The length of time required to complete the Flight Safety Engineering Analyst training program varies depending on the trainee's capabilities and previous experience as well as the launch schedule and availability of training supervisors. It is anticipated that approximately one year is required for the trainee to complete the program and become fully qualified.

(12) Cross Training - As the need arises, it may be necessary to train an individual on more than one vehicle. The entire training program

would not be repeated, however, vehicle unique or peculiar safety issues would be reviewed and analyzed by the Safety Analyst.

(13) Certification - The certification process for FSEA's is not formal. The trainee FSEA must demonstrate to SEY management the knowledge and skills described in paragraphs c.(1) - c.(12) sufficient to conduct flight safety support of a missile launch.

d. Flight Safety Project Officer (FSPO) - The FSPO is usually a civil service employee at the GS-12 level or above. He is responsible for the flight termination system from concept definition through operational use.
The FSPO training and certification program is a continuing task with the objective of providing the most qualified individuals to support Missile Flight Control operations. There are three types of formal FSPO training: 1) Initial training for newly assigned personnel, 2) Cross-training for initially certified FSPO's and 3) recurring and proficiency training. All newly assigned personnel undergo an initial training program leading to initial certification as a qualified FSPO, then cross-train into additional missile systems. FSPO's are also encouraged to become certified in the additional operational support positions of Back Azimuth, Program Outside Observer and Telemetry Observer. The FSPO who was the assigned FSPO during the design, testing and integration of a new-to-the-range missile system is the defacto certified FSPO for that system. Recurring and proficiency training is a continuous program for all personnel. Each individual is expected to exercise maximum initiative to complete training items in the minimum time, consistent with launch opportunities and training priorities as established by the Flight Termination Systems, Engineering and Operations branches.

(1) Training Officer - The Flight Termination System Branch Chief acts as the FSPO training officer. The Branch Chief may delegate the additional duty of training officer to the most experienced FSPO within the Flight Termination Systems Branch.

(2) Initial Training Program:

(a) Orientation Phase - This is primarily an indoctrination period. The FSPO training plan outlines the requirements of this phase, and the training officer verifies that the trainee has accomplished the requirements.

(b) Support Position Phase (Optional) - During this phase, the new FSPO will pursue checkout and certification in the Missile Flight Control positions of Back Azimuth and Program Outside Observer and Telemetry Observer. Training in these positions is IAW SE Operating Instruction 50-1, Range Safety Officer (RSO) Training and Certification.

(c) Console Phase - The new FSPO trainee is assigned to conduct prelaunch testing, launch countdown and actual vehicle launch, including preparation and review of appropriate documentation under the supervision of a certified FSPO. The trainee will attend and/or conduct operational meetings under supervision. He will interface directly with other Missile Flight

Control elements and organizations external to SEO. The time spent and number of elements to which the trainee is exposed is a function of his background experience and the manpower situation and launch rate. Upon completion of the orientation, support position and console training phases, the trainee will be considered for initial certification.

(d) Certification - A specific vehicle operation is selected by the training officer for the trainee FSPO checkout flight. The trainee will participate in all receipt-through-launch testing, documentation, coordination, countdowns and launch, and perform as the FSPO under close supervision of the training officer. Following satisfactory performance, the training officer and SEO Chief will execute a letter of certification for that particular program. For initial certification, a certificate signed by the Director of Safety is prepared and presented to the new FSPO by the Director.

(e) Records - One copy of the certification record and each letter of certification is maintained in the FSPO's training file. The FSPO maintains a composite record of operations support and supplemental training. A second copy of all certifications is maintained in the SEO training file.

(3) Cross-Training - FSPO's begin training on other missile systems as determined by the training officer and/or the Branch Chief. Checkout and certification requirements are identical to those outlined above.

(4) Proficiency Training - This type of training is a continuous process aimed at maintaining and enhancing the skills of certified FSPO's. Methods used include cross-talk sessions for discussion of real time problems encountered and briefings introducing or updating knowledge of new or continuing programs. A record of this training is also maintained.

(5) New Missile System FSPO Certification - Because a new system has not flown before, opportunities for normal FSPO certification do not exist. For this reason, the FSPO assigned that system during its design reviews, initial development and production shall be the defacto certified FSPO for that system during its first four missions. After the four missions, a letter of certification is executed and the certification process is the same as stated above.

(6) Currency - All FSPO's must maintain currency in their primary assigned system by performing at least one mission per year. Secondary systems must be supported by performing at least one mission every two years. Currency in Missile Flight Control observer positions shall be maintained IAW SE Operating Instruction 50-1.[23]

4. Missile Flight Control Systems and Support Personnel - The Missile Flight Control Systems provide the Range Safety Officer with real-time vehicle flight performance data, with the means to terminate the flight of vehicles that violate safety constraints and with the communications necessary to ensure safety criteria are met. The Missile Flight Control Center, MFCC, located within the Range Operations Control Center (ROCC) serves as the control area from which flight termination commands can be initiated in cases of errant or malfunctioning launch vehicles. The MFCC is comprised of several consoles and operating positions that help to insure that the RSO has the real-time display of launch vehicle position to assist in mission abort decision if flight criteria are violated. **Figure 15**[9] is a diagram depicting the physical layout of the consoles within the MFCC and **Figure 16**[9] is an overall system block diagram of the MFCC supporting systems.

The MFCC is the central control point for all WSMC vehicle flight control related activities. Different consoles are available to control and monitor the Range. Each console controller performs specific tests and simulations with his assigned systems to ensure they are ready for real-time launch support. The following is a functional description of the consoles and activities that support the RSO:

a. Real-Time Data Controller (RTDC) - The RTDC is responsible for controlling and validating the range tracking sensors providing data, and the vehicle flight control computers that process the data for display in the MFCC. Various tests, including simulations and playbacks of previously recorded vehicle launches, are used to insure that data to be displayed in the MFCC accurately and precisely presents vehicle position and performance. The RTDC console is capable of both automatic and manual selection of tracking sources. Two CRT displays provide visual vehicle position data and status information on all tracking systems.

b. Acquisition Data Systems Controller (ADSC) - The ADSC is responsible for providing "best source" acquisition data to the various tracking sensors. He performs tests and validations with the primary Acquisition Display System (ADS) and the secondary Digital Information Processing Systems (DIPS). Both of these computers provide unclassified acquisition data. The ADSC console is capable of both manual and automatic selection of acquisition data. Two CRT displays provide information on the quality of each radar track. The ADSC will deselect invalid tracking systems from being used in calculating acquisition outputs.

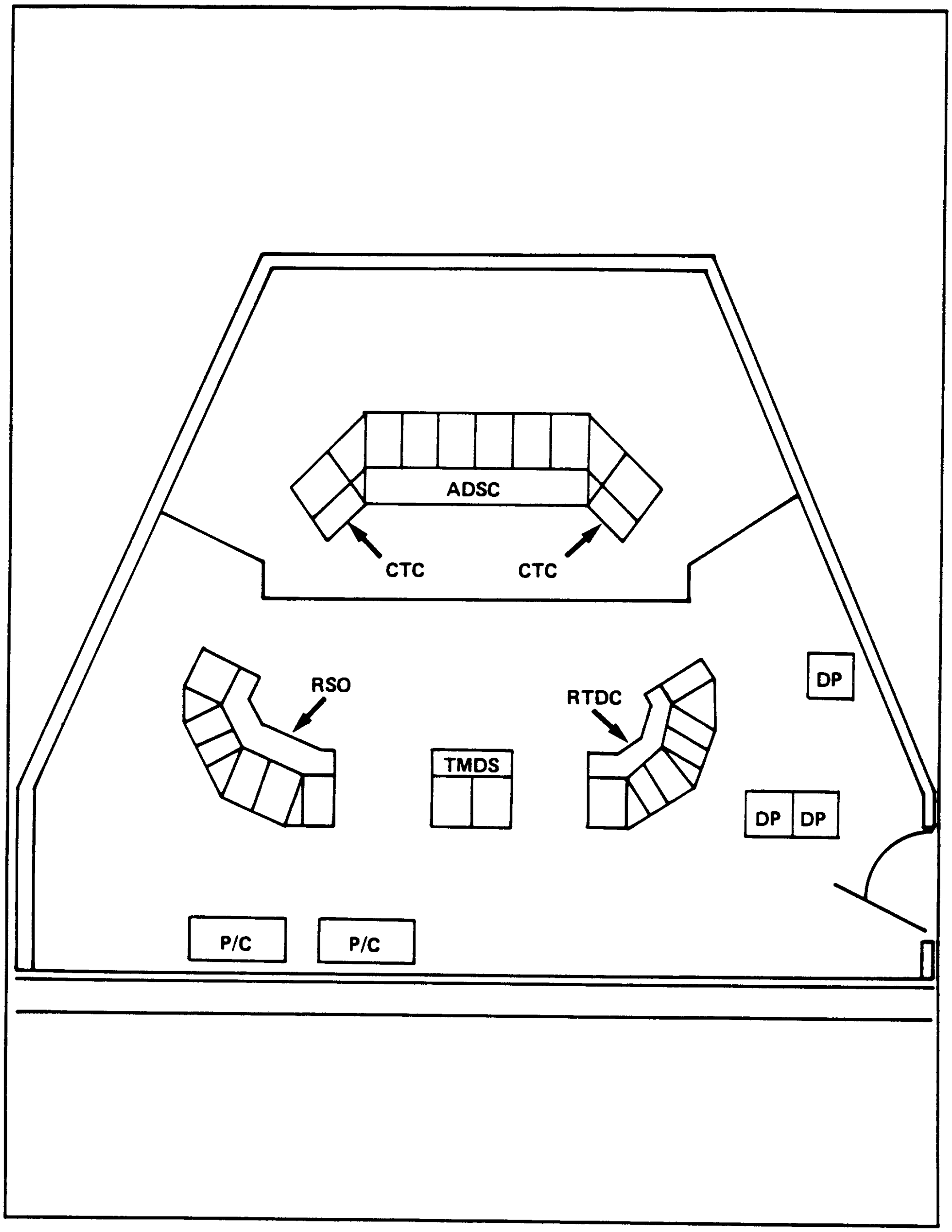

FIGURE 15. RANGE SAFETY CONSOLES

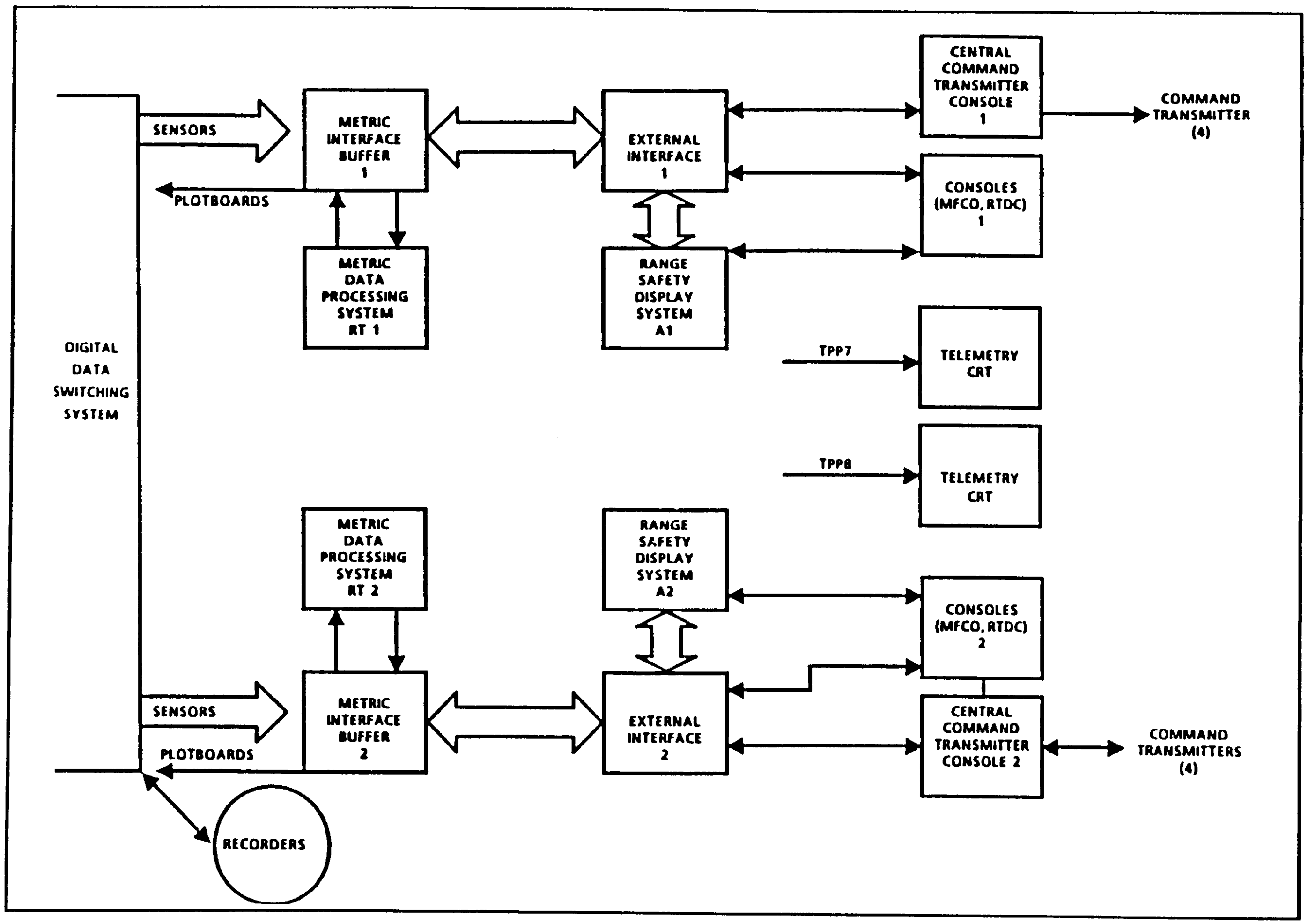

FIGURE 16. MFCC SUPPORT SYSTEM CONFIGURATION

c. RSO Console - The Range Safety Officer is responsible for missile flight control. From his console, he is able to monitor missile performance data acquired by radar, telemetry and optical tracking systems. The RSO console contains the control switches required to initiate the flight termination sequence. The Senior RSO is collocated on the same console and assists the RSO with problems during the prelaunch countdown and, when time permits, provides information and concurrence with the decision to terminate vehicle flight. The SRSO monitors displays and communicates with range safety support personnel and other agencies.

d. Telemetry Display System Console - The Telemetry Display System Console provides the RSO with sixteen bar charts, three analog display channels and telemetry data, plus various status messages. Database parameters can be selected for each channel to illustrate out-of-tolerence conditions by a change of color or flashing conditions. **Figure 17**$_9$ is an example of the types of data displayed on the telemetry CRT's.

e. Central Command Transmitter Console (CCTC) - The Central Command Transmitter Console operator controls the configuration of the remote command transmitters. It is a CCTC operator's responsibility to provide the RSO with a command transmitter site in proper configuration at all times. The CCTC is equipped with controls and readbacks for all functions required to control the command transmitter sites. The CCTC has displays to monitor the initiation of flight termination and control functions from the RSO console, or functions from the auto abort logic of the missile flight control computer. **Figure 18**$_9$ is a simplified block diagram of the CCTC. The CCTC is controlled by four microprocessors and their support logic. Each of these processors performs specific functions to insure no invalid commands are transmitted.

Inputs to the CCTC include auto abort functions generated by the metric data processing missile flight control computer (MDPS) and site status information. Outputs from the CCTC include command messages to remote sites and status inputs to the RSO and RTDC consoles.

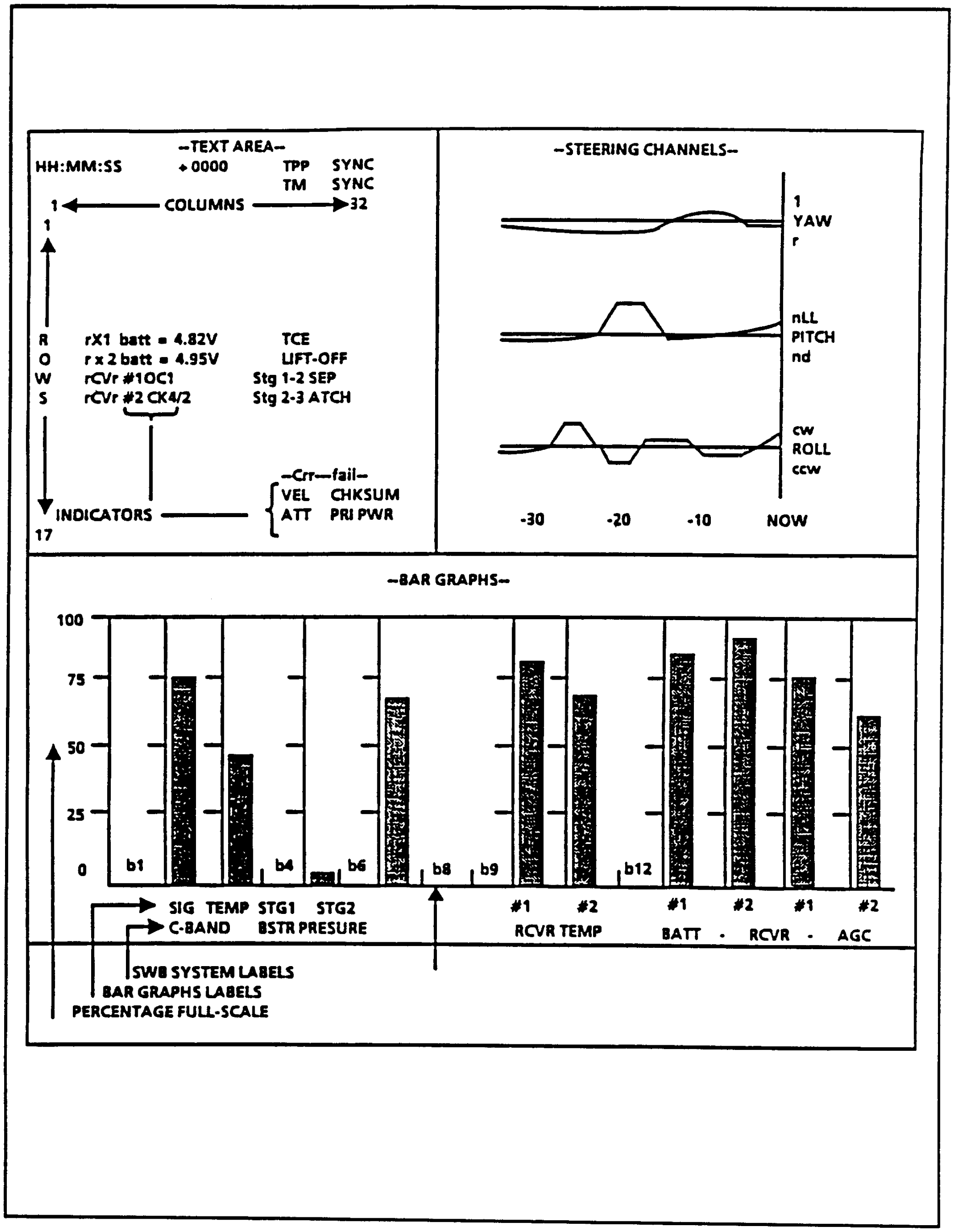

FIGURE 17. RANGE SAFETY TELEMETRY

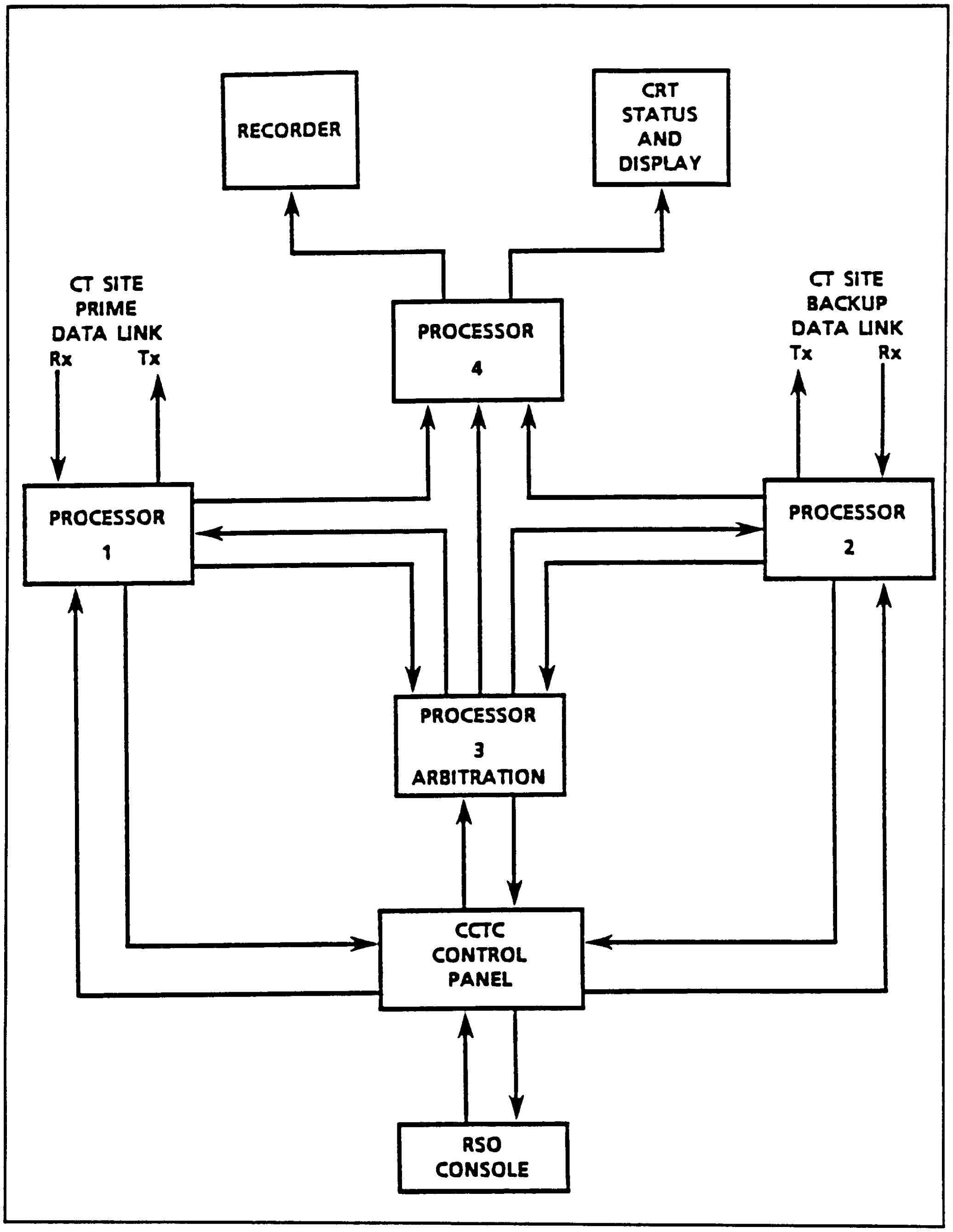

FIGURE 18. CENTRAL COMMAND TRANSMITTER CONSOLE BLOCK DIAGRAM

f. Computer/Display System - The flight control functions of the MFCC are supported by two computer systems. The dual Metric Data Processing Systems (MDPS) and the dual Range Safety Display Systems (RSDS) provide the MFCC with two complete independent range safety systems. The Acquisition Data System (ADS) provides acquisition data to all range control tracking systems.

The MDPS receives several different types of radar and telemetry data. From this data, MDPS generates a multi-station and several single station solutions of present position and instantaneous impact predictions. The multi-station solutions provide the capability to identify and correct invalid inertial guidance data and provide a higher quality of data on which to make flight termination decisions. The multi-station capability provides auxiliary benefits of helping identify invalid sensor data.

The RSDS provides the means by which real-time graphic and alphanumeric displays of vehicle performance metric data are presented to missile flight control personnel. These displays present not only the real-time vehicle information but background data including geography, nominal profiles, debris contours, etc.. See **Figure 19**[4] for a typical RSDS presentation. The various displays of vehicle performances are provided by RSDS and are selectable from the RSO/RTDC/ADSC operating positions.

g. Surveillance Control/Duty Air Controller (DAC) -Surveillance and clearance of land, sea and air areas in the vicinity of the WTR is necessary to ensure that missile launch operations take place in a safe environment. A service contract with the Southern Pacific Transportation Company (SPTC) provides for reporting of train traffic through VAFB during missile countdowns and launches. Advance notices to local harbor masters advise marine vessels and the U.S. Coast Guard of Danger Zone closures. The U.S. Coast Guard, in turn, broadcasts the information on the standard marine frequencies for all mariners. Ships at sea are advised of the missile hazard area by merchant ship broadcasts (MERCAST) and Hydrographic Notices to Mariners in the Pacific (HYDROPACS). Aircraft pilots on overseas and domestic routes are advised of missile hazard areas by a Notice to Airmen (NOTAM).

The Duty Air Controller (DAC) controls those geographic areas specifically assigned to the Range during launch operations, exercises control of all traffic, surveillance and display equipment to assure that airspace, water and land areas specified by SEY are clear of unauthorized ships, aircraft, vehicles, trains and personnel during launch, and informs the RSO of the current status and changes in status of the hazard and impact areas. The SPTC provides a trainmaster stationed at Surf station for WSMC missile operations. The trainmaster is in communication with the DAC via direct telephone line. The DAC provides appropriate telephone notices and radio broadcasts on T-1 day. On all launches that require protection of SPTC railroad track, the DAC ensures that an operator is provided for the Automated Train Surveillance System (ATSS).[24]

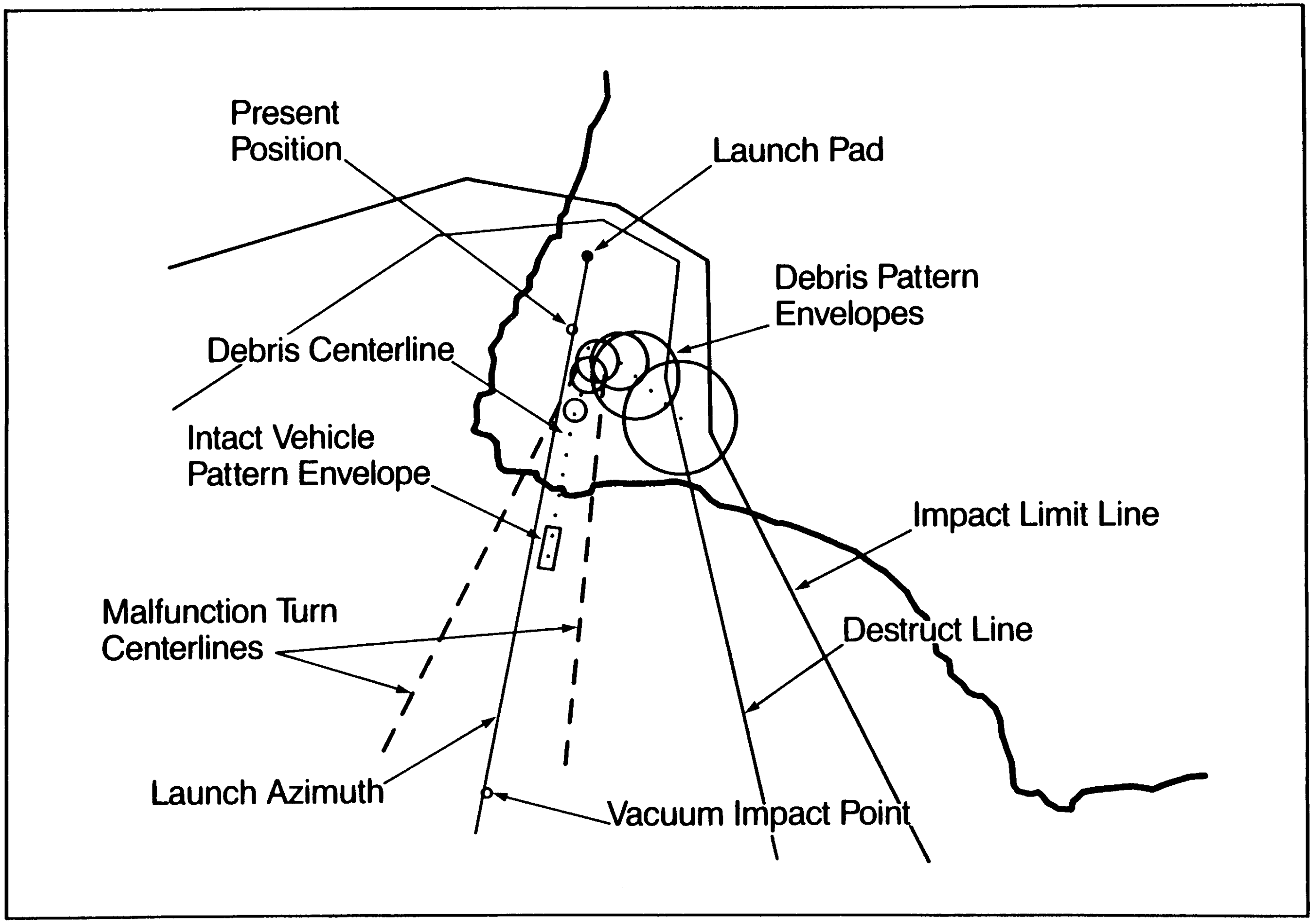

FIGURE 19. TYPICAL RANGE SAFETY DISPLAY FOR ORBITAL LAUNCHES

h. Automated Train Surveillance System - The ATSS consists of sensors located along the tracks at various points from Guadalupe (north of VAFB) to Gaviota (southeast of VAFB), a central processor and displays in the Missile Flight Control Center and the Area Control Center (ACC). Passing trains activate the sensors and the processor displays their signals in the MFCC and the ACC and may necessitate a hold of a launch. The ATSS provides the RSO and the DAC with real time information on train movement so that they can predict times into, and out of, protected areas. The ATSS processor will also pass milemarker locations of trains to the Range Safety Display System for real time display.

i. Sky Screen - The Skyscreen system is made up of three elements: the Skyscreen observer, the Skyscreen TV and the associated instrumentation and communications needed to input the Skyscreen information to the MFCC. Two Skyscreen systems support each launch and are designated Back Azimuth and Program. The Back Az position is located uprange from the launch point along the flight azimuth and the Program position is located cross-range from the launch point. The Skyscreen observer and TV may or may not be collocated. Skyscreen operators provided by the CTSC set up and check out the Skyscreen systems prior to T-60 minutes and operate the Skyscreen TV and communication systems.

Skyscreen observers are individuals who have been certified by WSMC/SEO to perform this duty. Both Back Azimuth and Program observers report visual indications on the early phases of missile flight directly to the RSO.

The Skyscreen TV consists of a portable TV camera system, support van and microwave equipment, and provides real time television coverage of vehicle performance to the RSO.

j. Communications - An extensive WTR communications network connects the sites and stations of the Range and other facilities. In order to achieve the highest degree of flexibility and reliability, the network uses communication satellites, undersea cables, microwave links, HF, VHF, and UHF radio and various land lines. Communication systems include redundant and non-redundant Voice Direct Lines (VDL's), dial lines, networks, teletype, non-tactical radio and monitoring.

A wide range of circuits is used by the RSO for communications during prelaunch countdown and real-time launch operations. These include circuits to local Range Safety personnel, supporting contractors and other government organizations. This communication network allows statusing of Range Safety requirements during prelaunch activities to assess readiness to support launch operations. It also provides communications to critical Range Safety support stations during real-time flight of a vehicle.

k. Emergency Response - In addition to normal support functions, VAFB provides a Launch Support Team for each launch operation. This team is composed of select emergency response personnel, with their equipment, who are prepared to cope with such hazards as fire, explosives, toxic propellants and hazardous radiation materials, as well as to perform rescue operations. The composition of the team is tailored to the requirements of each particular vehicle/payload. The Support Team responds to impact/abort on the launch pad and impact on or off VAFB. For off-base impacts, the Support Team assumes the role of assisting the civil authorities who have the responsibility for controlling the impact site.

5. Safety Restrictions

a. Flight Azimuths - The acceptance or rejection of a particular launch azimuth does not depend, generally, upon the space launch vehicle or the pad from which it is launched. Flight azimuths are limited by the ability to contain debris from a malfunctioning or destroyed flight vehicle. Launch azimuths for orbital missions that have been approved in the past range from ~ 147 - 213 degrees. Azimuths outside this range are considered restricted; however, with proper justification, approval might be granted to fly these azimuths. Missions that might be considered could include national defense, national security, or some other high priority launches.

b. Danger Areas/Missile Flight Hazard Area/Missile Flight Caution Area - The Air Force launch ranges are governed by AF Regulation 127-100[25] where quantity-distance separation of explosives from various facilities and activities is involved. This regulation implements the Department of Defense Ammunition and Explosives Safety Standards outlined in DOD Directive 6055.9-S. It contains various tables showing separation distances that are acceptable between different classes and quantities of explosives and unrelated, exposed facilities such as public highways, schools, inhabited buildings, etc.. Some key terms that are used follows:

- Inhabited Building (IHB) Distance - Inhabited buildings include structures or other places not directly related to explosives operations where people usually assemble or work. This distance must be provided between explosives locations and base boundaries.
- Net Explosive Weight (NEW) - This is the net explosive weight, or TNT equivalent weight, of the explosive.
- K-Factor - This is used in most of the tables and is a scaled distance equal to distance (ft.) divided by the cube root of the NEW. Figure 5-6 of the regulation plots overpressure (psi) against K-Factor (ft./lbs.$^{1/3}$). Thus, the distance can be determined at which any given overpressure will be felt for a particular NEW: Distance (ft.) = K x (lbs.)$^{1/3}$

In order to establish a **Danger Area** around a launch pad or hazardous buildup facility based upon blast or overpressure, range personnel must decide how much overpressure (psi) will be allowed at the area boundary. With this overpressure, the chart in Figure 5-6 is entered and a K-Factor is determined. Then, with the NEW of the launch vehicle or other hazardous items, the distance from the pad or facility to the danger area boundary can be computed using the above formula. Of course, other factors may dictate a larger danger area than blast, such as toxic propellants or fragments. In addition, if space is not a problem, a larger area may be used for convenience in locating fallback areas, roadblocks, etc.

At the WSMC, until recently, a **Hazard Area Corridor** was drawn as a circle about the launch point with tangents extending along the flight azimuth, which was based upon an overpressure of 0.5 psi. It was defined as, "That area where significant danger to personnel and equipment would exist in the event of a malfunction during the early phases of missile flight. It is the ground and air space extending to an unlimited altitude, and including the entire area where the risk of serious injury, death or substantial property damage is so severe that it necessitates exclusion of all personnel and equipment not needed to conduct the launch operation. Personnel required to be in this area during a launch operation must be located in blast-hardened and approved shelters."

A similar **Caution Area Corridor**, based upon a 0.4 psi. line, was drawn outside the **Hazard Area Corridor** within which essential personnel could operate, with Range Safety approval. It was defined as, "That ground area outside of the missile flight hazard area where injury or property damage could occur because of a missile flight failure. This area is restricted and only essential personnel are allowed to remain within the missile flight caution area during launch operations."

However, with the advent of the Launch Area Risk Assessment (LARA) program at WSMC, these areas are drawn by computer and are based upon risk probability lines ($1x10^{-5}$ for Hazard and $1x10^{-6}$ for Caution). WSMC personnel plan to use the LARA program to construct danger areas for some of the ESMC launches until the LARA capability can be established at ESMC. In the near future, both ranges will use the same criteria for risk analysis and danger area construction. See **Figure 20** for typical Titan Caution and Hazard Corridors.

c. Impact Limit Line - A line defining a limit beyond which debris from a flight vehicle must not be allowed to impact. Refer to **Figure 19** for a typical launch area Impact Limit Line.

d. Destruct Lines - Flight termination lines, or destruct lines, define the safety limits used for determining when to terminate vehicle flight. Activation of the FTS by the RSO upon violation of the destruct line prevents significant debris from penetrating the Impact Limit Line (ILL). Destruct line location is determined by accounting for system delays, data inaccuracies (including tracking systems errors) and debris dispersions. The RSO's decision and reaction time of approximately three seconds is used for orbital missions from the WTR.

The destruct line is normally constructed between the Impact Limit Line and the planned nominal trajectory of the vehicle. See **Figure 19**.

If the Instantaneous Impact Point (IIP) crosses the destruct line and flight termination action is taken by the RSO, the launch fragments with ballistic coefficients (W/C_DA) greater than 10 $lbs/ft.^2$ should not impact beyond the ILL.

Figures 21-24 show typical destruct lines used for various space vehicles launched from the WTR.

e. Debris Patterns - Dynamic, or moving, impact debris circles are used in real-time by the Range Safety Officer. These debris patterns define the area within which vehicle fragments are expected to fall, i.e., the dispersion for a particular instant of time. When seen on the RSDS, the pattern is continually changing and growing as the flight of the vehicle progresses. In paragraph d.

above, it was stated that when the vacuum Instantaneous Impact Point crossed the destruct line the vehicle would be destroyed. The information in the debris pattern is used as an aid to determine if destruct action is necessary. If the debris pattern appears to threaten a populated area on land when the IIP crosses the destruct line, the Range Safety Officer has the option to wait if it appears that the debris pattern will clear the areas if the flight termination command is delayed. Data from the T-7 or T-6 hour wind measurement is taken to update the data base for debris pattern generation. A typical debris pattern is shown in **Figure 19**.

f. Impact Areas - These are calculated areas within which parts of the missile are expected to impact during a normal flight. These parts are such items as expended booster stages, payload fairings or any other significant parts that are jettisoned along the flight path. These impact areas must be in the ocean. Range Safety will not allow a launch countdown to proceed to T-0 when it is determined by surveillance that people are within these impact areas.[3]

g. Mission Rules - The Mission Rules document, which is coordinated by Range Safety, is an agreement between the launch agency and the WSMC Commander. These rules specify in detail the flight safety requirements and procedures unique to a specific mission. Some examples of typical mission rules are:

(1) No Downrange Motion (straight up) - If the Instantaneous Impact Point (IIP) does not progress downrange, vehicle flight will be terminated at "red time". "Red time" is the earliest time at which destruct action is required to contain the fragments of a non-nominal vehicle within the Impact Limit Line. The computation of "red time" includes vehicle turn rates, fragment mixes, RSO reaction time and vehicle hazard radius.

(2) Destruct Line Violation - Vehicle flight will be terminated if the Instantaneous Impact Point crosses a destruct line.

(3) Erratic Vehicle - A grossly erratic vehicle flight will be terminated to prevent loss of command control due to either impending vehicle breakup, impact or loss of command transmitter coverage.

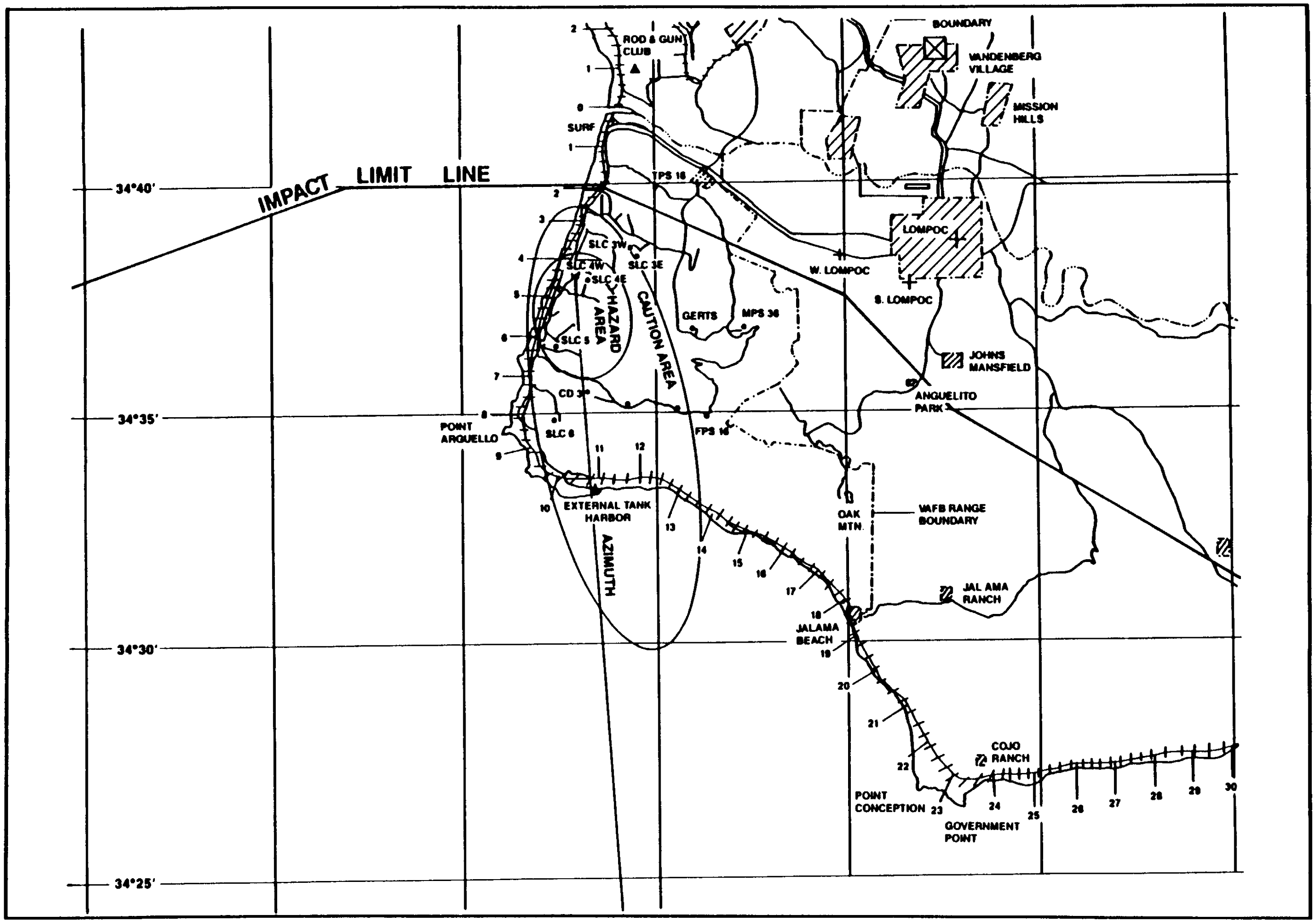

FIGURE 20. TYPICAL TITAN CAUTION AND HAZARD CORRIDORS

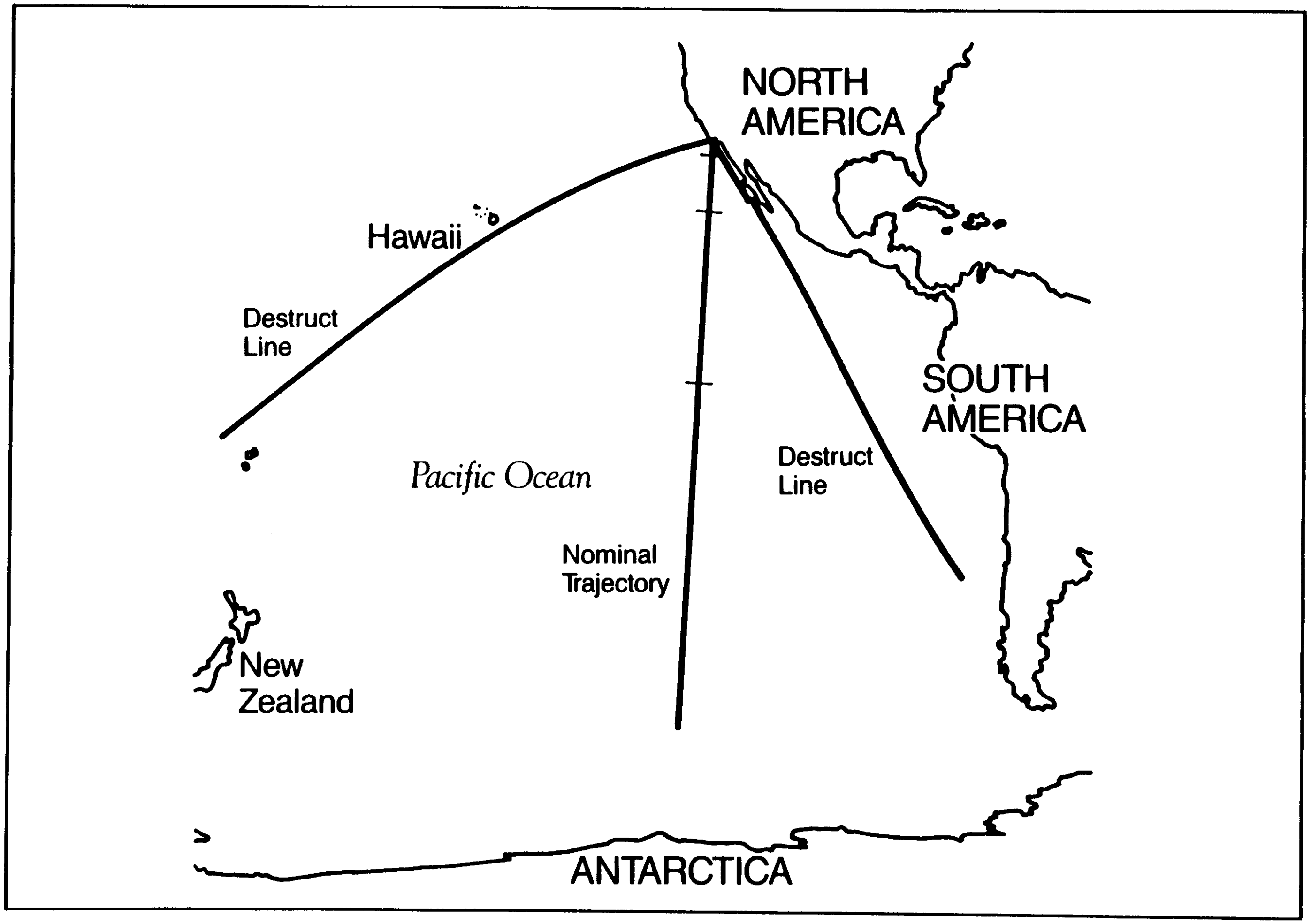

FIGURE 21. TYPICAL ATLAS DESTRUCT LINES

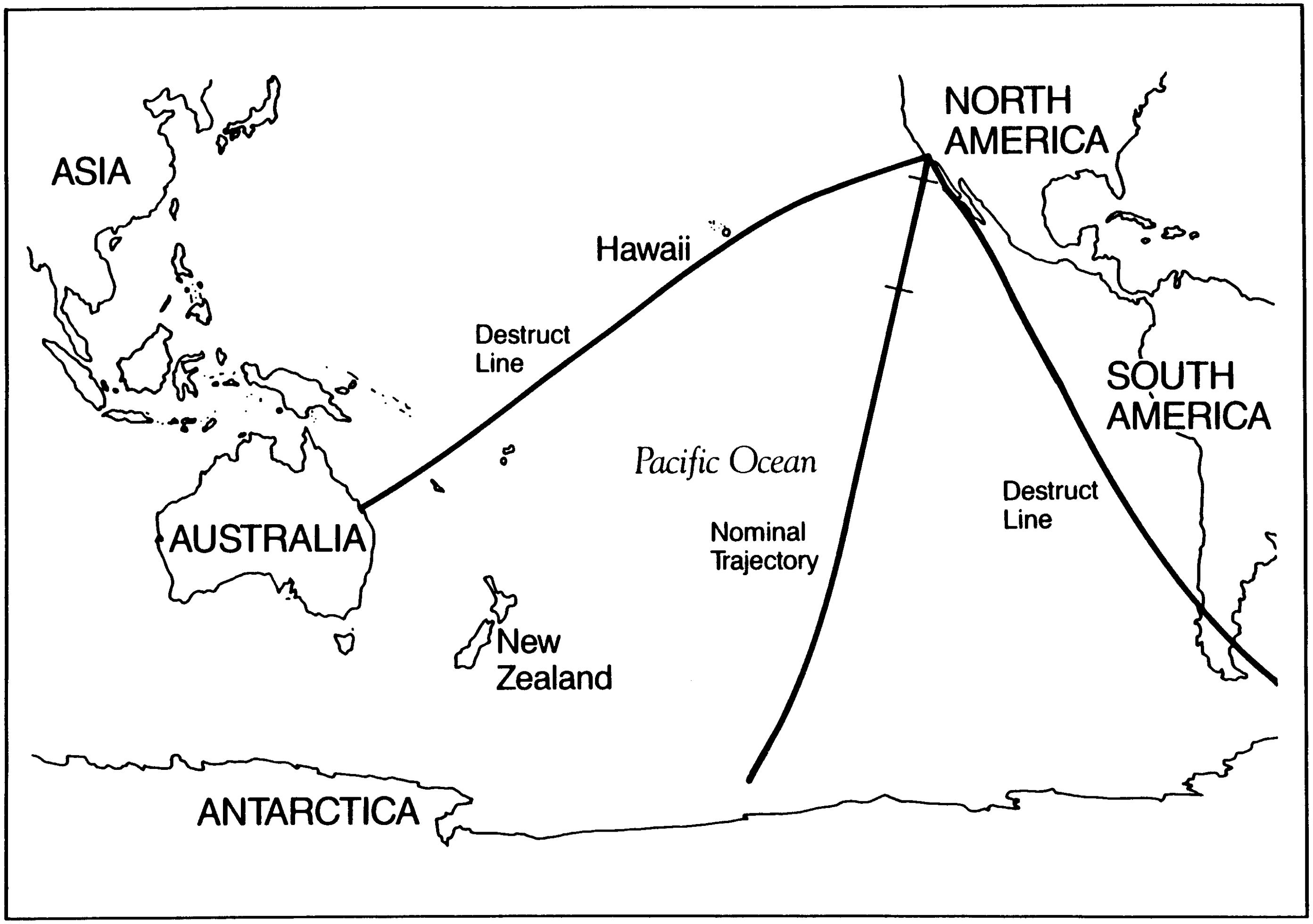

FIGURE 22. TYPICAL DELTA DESTRUCT LINES

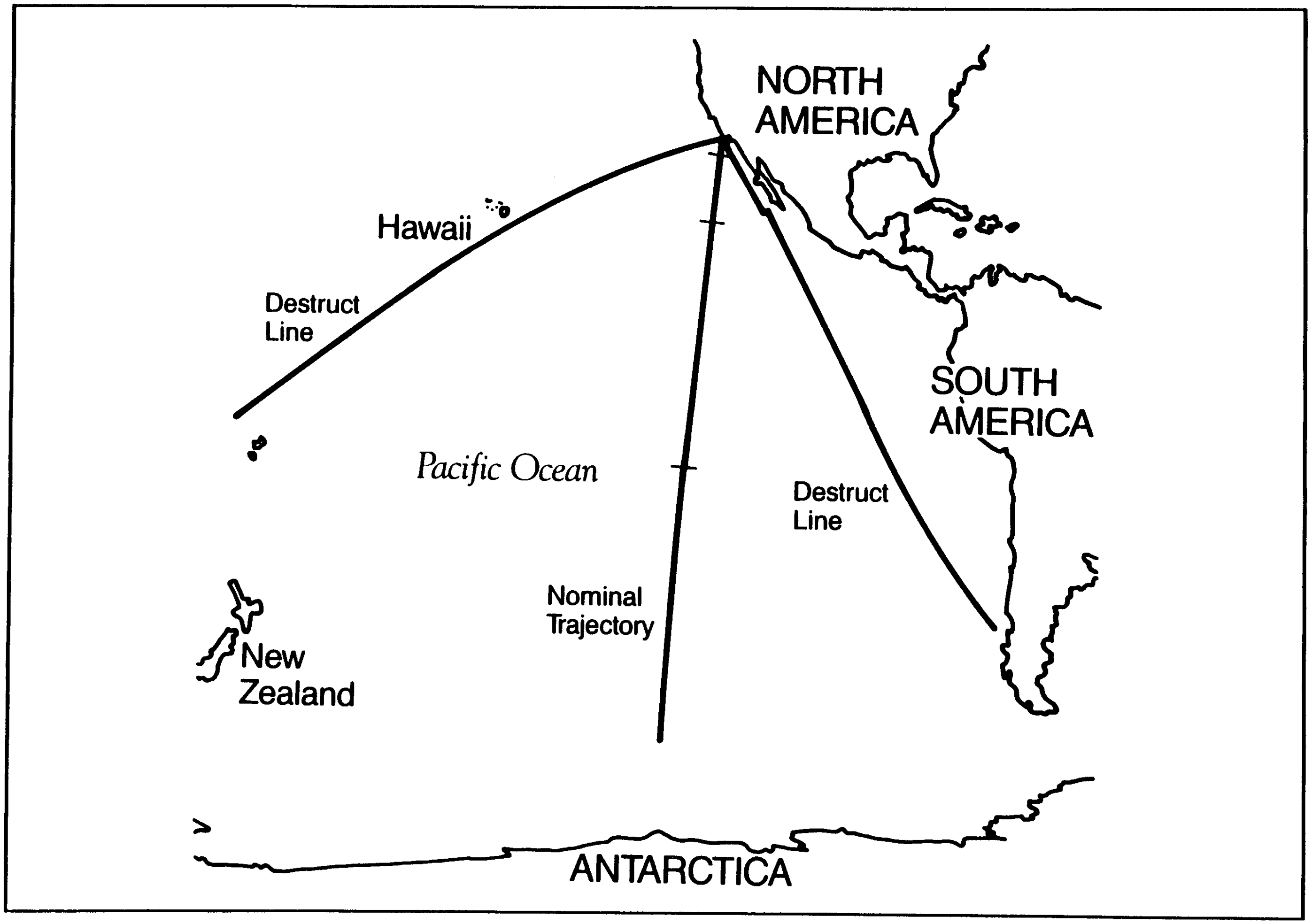

FIGURE 23. TYPICAL SCOUT DESTRUCT LINES

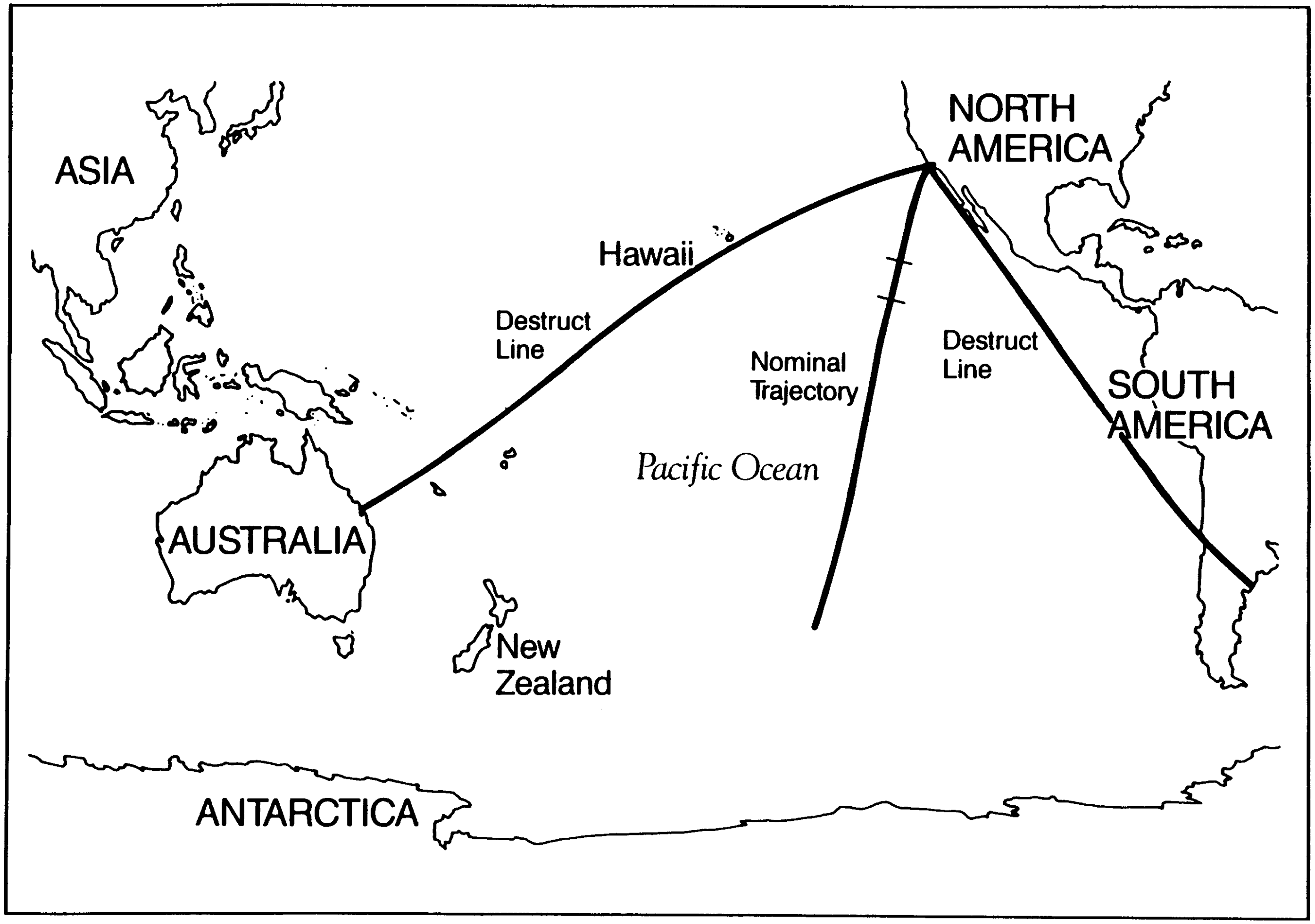

FIGURE 24. TYPICAL TITAN DESTRUCT LINES

(4) Unknown Vehicle Performance - The following "UNKNOWNS" will result in vehicle flight termination:

- No radar track by "amber time" and outside observers cannot see the vehicle. "Amber time" is the earliest time when a vehicle has sufficient energy to reach the ILL. If no sensor has acquired vehicle track by "amber time", the RSO may terminate the flight.
- No radar track but outside observers can see the vehicle. Flight will be allowed to continue until shortly before the critical time to endanger Hawaii.
- All adequate tracking data is lost. Time of flight termination will depend on "critical times", i.e., "amber time" (to endanger populated areas) and vehicle systems status and performance as best determined by the RSO. "Critical times" were developed because of the possibility of losing all sensor data during powered vehicle flight.

"Critical times" indicate various starting times from the nominal trajectory and the number of seconds it would take the vehicle to cross the destruct line from the given starting times.

h. Range Safety Critical Items - For each mission, the Range Safety Officer determines the critical/mandatory items necessary to meet minimum safety requirements. These mandatory items include:

- Radar tracking beacon on the vehicle
- Vehicle command destruct systems
- Range Safety Displays
- Computer systems (Metric Data Processing System)
- One complete (dual) ground command destruct system that can provide coverage from lift-off to command destruct receiver off
- Two independent tracking sources from lift-off through powered flight, until orbital insertion or loss of signal (LOS).
- Acquisition source

Loss of capability of any of these items during the launch countdown will result in a "hold" being called by the RSO. If a critical item fails, then the countdown will not resume until the item is functional and minimum Range Safety requirements are attained. It is not common practice for Safety to waive any of these items; however, that authority is vested in the WSMC commander. It must be recognized that, in most cases, he will be unwilling to accept the increased risk exposure to the public. This increased risk to the public is difficult to quantify since such application is a real-time command decision. The practice of using "mandatory" items as criteria for allowing launch of space vehicles confirms the fact that public safety issues are of major concern to WSMC Safety.

i. Launch Area Risk Analysis (LARA) - The LARA program computes probability of impact (P_i) and expectation of casualty (E_c) for predetermined locations with a specified population. It is used as a tool in establishing prelaunch hazard limit values associated with the planned mission. The program combines Range User-supplied data such as vehicle failure modes, breakup schemes and trajectory, and subjects them to vehicle flight control constraints such as destruct lines, Impact Limit Lines, three sigma Instantaneous Impact Points, RSO reaction times, etc.. The resulting predictions of vehicle fragment impacts are drag and wind corrected, based upon either standard IRIG atmosphere or upon forecasted or actual launch day winds.

The LARA debris plot program is used to plot the results of a LARA analysis on VAFB area maps. The plots contain the launch azimuth, impact limit line, one of six different destruct trajectories and the loci of debris impacts as a function of time from launch. Different loci are plotted for various ballistic coefficients and winds.

6. Toxic Propellant Hazards

a. General - The commercial candidate vehicles which involve toxic propellants of concern are the Titan 34D and the Delta. These propellants are hypergolic, that is, they spontaneously ignite when fuel and oxidizer are brought together. The Titan 34D uses Aerozine-50 (A-50) for fuel and Nitrogen Tetroxide (N_2O_4) as oxidizer for stages 1, 2 and the Transtage, plus N_2O_4 for the Thrust Vector Control (TVC) system on each SRM. The Delta uses A-50 as fuel and N_2O_4 as oxidizer in its second stage.

b. History - In 1985, the National Research Council's Committee on Toxicology (NRC-COT) recommended the 60-minute public emergency exposure limit for N_2O_4 be reduced by 50% as a means to further protect the public from this toxic hazard. In addition, they recommended that the public emergency exposure limits for Aerozine-50 and N_2H_4 be reduced by factors of 60 to 120. The new toxicity levels for the propellants of concern are shown in **Table 12**[26], and are published in Volumes 4 and 5 of "Emergency and Continuous Exposure Guidance Levels for Selected Airborne Contaminants".

In 1986, the Air Force Surgeon General accepted the recommendations and directed their implementation at all Air Force propellant handling locations. However, even though accepted, the recommended N_2O_4 reduction is still being evaluated.

As the maximum allowable exposure limits are reduced, the lengths of the Toxic Hazard Corridors (THC) are correspondingly lengthened. (The THC is an area within which toxic propellant vapor concentrations are predicted by meteorologists to exceed the public emergency exposure limits). This has caused concern regarding the operational impact of the reduced limits. The Range Commanders for the major test ranges feel that accident scenarios which cause potential excursions beyond maximum allowable exposures might become the rule rather than the exception. They have asked for information on the rationale for these lower limits so that they might assess and manage the risk to the public.

TABLE 12. TOXICITY MATRIX						
				1985 EMERGENCY LIMITS		
	TLV/TWA	IDLH	STEL	30 MIN *	60 MIN	2 HOUR
HYDRAZINE	0.1 PPM	80 PPM	N/A	0.24 PPM	0.12 PPM	0.06 PPM
MMH	0.2 PPM	5 PPM	N/A	0.48 PPM	0.24 PPM	0.12 PPM
UDMH	0.5 PPM	50 PPM	N/A	0.48 PPM	0.24 PPM	0.12 PPM
AEROZINE-50	Vapors from a standing source will be initially almost all UDMH. Use the more stringent criteria of UDMH or Hydrazine in all cases.					
NO_2 (N_2O_4)	3.0 PPM	50 PPM	5 PPM	2 PPM	1 PPM	0.5 PPM

TLV	Threshold Limit Value
TWA	Time Weighted Average
IDLH	Immediately Dangerous to Life or Health
STEL	Short Term Exposure Limit
MMH	Monomethyl Hydrazine
UDMH	Unsymmetrical Dimethylhydrazine
NO_2	Nitrogen Dioxide
N_2O_4	Nitrogen Tetroxide

* The 30-minute exposures are extrapolations from the 60-minute exposures. This extrapolation is necessary as dispersion models are based on 30-minute exposures.

c. Toxic Exposure Protection - The WSMC has a broad safety plan which provides protection to the public from toxic exposure:

(1) 1 STRADR 127-200, "Missile and Space Systems Mishap Prevention Program", final version in coordination. This regulation includes references to many pertinent documents from a large variety of sources, such as the American Society of Mechanical Engineers (ASME) Codes (i.e., Boiler and Pressure Code), the National Fire Protection Association (NFPA) Codes, the National Electric Code (NEC), OSHA Standards and complementing AFOSH Standards, AFSC Design Handbooks, ACGIH Threshold Limit Values (TLV), American National Standards Institute (ANSI) Standards, Air Force, Army and Navy documents, Chemical Propulsion Information Agency (CPIA) publication No. 394, "Hazards of Chemical Rockets and Propellants" and many others. The scope of the WSMC Safety Program is intended to encompass all Range Users. WSMCR 127-1 provides specific requirements, criteria and guidance to protect personnel from inordinate risk, injury or illness, and property from loss or damage due to WSMC operations. This means that undue risks to the public will not be accepted.

WSMCR 127-1 also requires that both ground propellant transfer systems for loading/unloading missile/space vehicles and airborne propulsion systems be at least single failure tolerant. Systems in which failure could have catastrophic results are required to be dual failure tolerant. The regulation discusses compatibility and contamination, valves, pressurization/venting, ignition hazards, liquid propellant facilities, propellant/propulsion system test requirements and propellant/propulsion system data requirements. It specifically requires that toxic vapor vents be located and designed to prevent personnel exposure above approved levels.

(2) Hazardous Propellants - Range Users must provide data to the WSMC on hazardous propellants to include:

- Specific health hazards such as toxicity and physiological effects
- TLV's, maximum allowable concentration (MAC) for an eight hour day, five days per week of continuous exposure
- Emergency tolerance limits including length of time of exposure and authority for limits
- Maximum credible spill size (volume and surface area)
- Material incompatibility problems in the event of a spill
- Protective equipment to be used in handling and using the propellant, to include manufacturer, model number and when equipment is to be used in an operation
- Vapor detection equipment to include manufacturer, model number, specifications, operating limits, type of certification and general description
- Recommended methods and techniques for decontamination of areas affected by spills or vapor clouds and hazardous waste disposal procedures

(3) Standard Methods - The Center practices a number of standard methods of assuring toxicological safety. Some of this methodology is described in the following paragraphs:

- Each toxic propellant operation is monitored by a Range Safety representative: the Complex Safety Officer (CSO) or the Complex Safety Technician (CST). He has the authority to stop any operation deemed too hazardous.
- The WSMC/Office of Staff Meteorology operates a weather facility at VAFB which has special capabilities to provide weather forecast information peculiar to toxic propellant operations. Part of the capability planned for the near future is in a system called MARSS (Meteorological And Range Safety Support), which is discussed separately. The Weather Facility can provide a current forecast at the beginning of each toxic propellant operation and can obtain a prediction of downwind travel of any hazardous vapors.
- Each hazardous toxic propellant operation is controlled by a Safety-approved operating procedure. There is also a Launch Complex Safety Plan for these recurring hazardous tasks. Safety

uses these documents to establish internal controls. Each procedure has an emergency section to cover the inadvertent release of toxic propellants/vapors. Included is a shutdown procedure so that the amount of an inadvertent release is minimized.

- Medical personnel are placed on stand-by, either near the work location or at the local dispensary. They are alerted as to the type of hazard involved for pre-planning purposes.
- Pump Stations are brought up to operating pressures on water/deluge systems for propellant transfers. Fire Protection personnel are placed on stand-by in the work area. These personnel are specially qualified to respond to toxic propellant/vapor releases. Fire trucks supporting propellant operations have a foam generating capability which can be used to lay a foam blanket over a propellant spill, thus inhibiting the release of significant vapors.
- Each work location where toxic propellants are handled has a warning light system to identify the level of hazard involved: Green for "all clear", amber for "caution", red for "danger" and flashing red for "emergency evacuation".
- Each warning light system is complemented by a public address (PA) system used to announce area status or emergency conditions. In addition, there is an Aural Warning System that provides information of impending danger. This system can over-ride all PA systems on the WSMC.
- Venting operations are strictly controlled and are dependent upon favorable meteorological conditions. This generally means the lapse rate must be negative and winds blowing in a favorable direction. The lapse rate gives some assurance that vapors will generally dissipate vertically and horizontally in the direction of the wind. Planned vent operations are restricted to favorable conditions.

(4) Meteorological and Range Safety Support (MARSS) - The MARSS System is a complex computer program designed to be an aid to safety personnel in planning for, or reacting to, inadvertent releases of toxic propellants. This system has been purchased by the WSMC, but is not operational at the present time.

7. Safety Analysis

a. Introduction - This section presents a baseline of the public risks for launches from the WTR. The generic risk assessment presented herein is based on the WTR launch history, current commercial launch vehicle characteristics and experiences of the RTI staff. It must be noted that the WTR and other Ranges adopted a FTS or "Command Destruct" philosophy in the early 1960's. This philosophy has always assumed that the Flight Termination System (flight and ground components) provides an acceptable means of control to prevent unacceptable public exposure from the launch of space vehicles. Hence:

- Most public risk studies performed by the Ranges are based on the assumption that the FTS prevents unnecessary public exposures.
- The reliability of the FTS (not the launch vehicle reliability) was assumed to be the controlling factor in assuring that public exposures did not occur.
- The FTS is utilized to prevent launch vehicles from exposing the public to risks from an errant vehicle and to disperse vehicle propellants in the event of a launch failure.[8]

b. WTR Launch History - Following is a brief discussion of the WTR experiences in providing range safety protection for the launch of launch vehicles:

(1) General - The WTR has been conducting orbital launches since the early 1960's. Most of the procedures and public safety criteria utilized by the WTR have evolved over years of experience. The procedures and criteria for public safety that are utilized to protect the public were evaluated by the Range Commander's Council and the subordinate Missile Flight Safety Group in the early 1960's. The WTR has conducted the launching of many types of launch vehicles developed in the United States space programs and established the flight safety rules for these missions, as well as the design specifications for the flight safety systems utilized to provide for public protection.

The Range Safety system at the WTR has accommodated a wide variety of programs including ballistic missiles, cruise missiles, synchronous orbital missions and earth observation missions. Over 1600 launches have been conducted from the WTR. No off-range impacts have been identified.

(2) Flight Termination System (FTS) Reliability -The WSMC requirement for the flight termination systems is a reliability of 0.999 at the 95 % confidence level. FTS's flown at the WTR are subjected to rigid design review, test and quality assurance standards. The actual flight history reliability for the more than 1600 major launches shows that no FTS failures (single string or fully redundant) have occurred. Since there were no recorded failures at WSMC of the FTS system, a conservative estimate is to assume that a total FTS failure could occur on any subsequent launch. On this basis, the FTS failure probability can be estimated to be 1/1600 or ($6x10^{-4}$) with high confidence. The observed FTS reliability is then: 1-(1/1600) = 0.9994.

c. Public Exposures to WSMC Space Launches

(1) Public Hazard Event Tree - The events required for an exposure of the public to a hazard from a space vehicle launch are depicted in **Figure 25.**[8] The event tree for WTR experience illustrates the approximate probabilities and conditional events required to expose the public to a launch vehicle failure.

(2) Launch Vehicle Failure Probability/Reliability -The historical reliability and failure rates of launches from WSMC, for the planned

commercial launch vehicles, are shown in **Table 13**.[27] As shown, the proposed commercial launch vehicles have a historical failure rate of approximately 4-7 %. These launch vehicles were produced to government standards and quality assurance programs. It is unlikely that the current failure rates will be any different for commercial launches. For Event #1 on the event tree, it can be assumed that approximately 95% of all space launches at the WTR are successful. A successful launch results in booster stages and other discarded debris impacting within planned areas and the eventual decay from orbit of all hardware placed in earth orbit. Shown by event tree boxes (a-a.3) are the results and estimated exposure levels to shipping and for reentering debris. Planned Air Traffic exposures (a.2) are assumed to be less than 10^{-6}, since the FAA clears air traffic from all impact areas.
Approximately 5% of all WTR launch vehicles fail during an attempted orbital mission. These failures do not necessarily result in a public exposure. Experience has shown that approximately 50% of these failures occur during the early launch phase, i.e., 0 to 60 seconds after launch (Event #2). The conditional probabilities estimated at each event block are shown in parenthesis within the event block. The remaining 50% of the launch failures occur down-range from the launch site and are controlled by Event #7.

* Launches from WTR only

TABLE 13. REPORTED ORBITAL LAUNCH VEHICLE RELIABILITY*

Launch Vehicle	Flights	Failures	Reliability %	Failure Rate %
Titan III/34D	95	4	95.8	4.2 (1 in 24)
Atlas	60	4	93.3	6.7 (1 in 15)
Delta	36	2	94.5	5.5 (1 in 18)
Scout	45	2	95.4	4.4 (1 in 22)
Summary	242	12	94.7	5.3 (1 in 19)

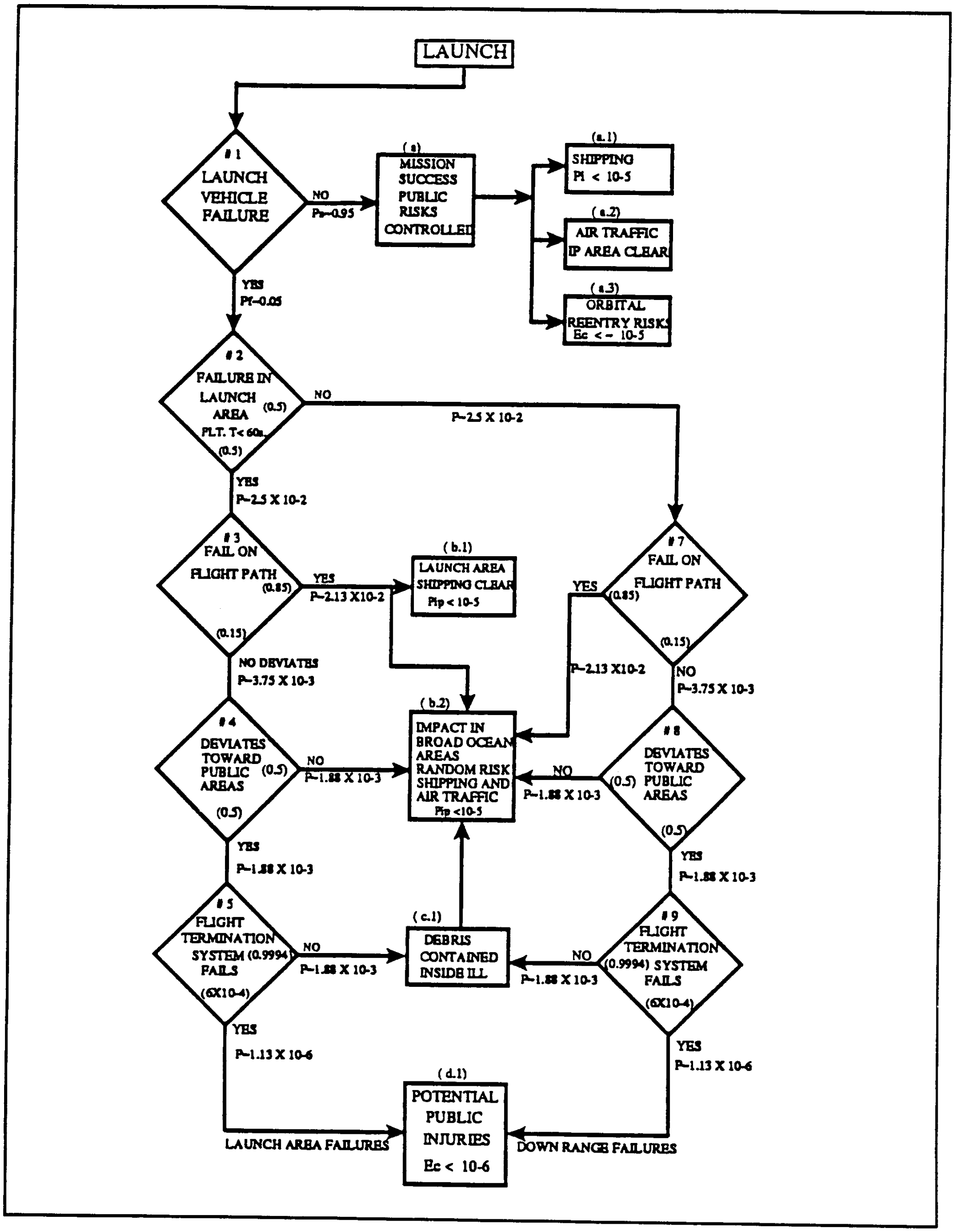

FIGURE 25. PUBLIC HAZARD EVENT TREE

Examining those failures that do occur in the launch area, experience shows that approximately 85% of the launch vehicle failures occur on the original flight path (Event #3). Failures of the propulsion system(s) normally predominate the failure modes. Loss of thrust, lost thrust vectoring, propulsion system explosions and vehicle structural failures due to turns result in little displacement from the original flight path. In many of these failures, complete destruction of the launch vehicle occurs before flight termination commands can be issued. The results of such failures pose a significant hazard to shipping near the launch site (b.1) and off-shore oil rig platforms. Launch hazards to shipping and boating interests are controlled by surveillance out to a range of approximately 20 miles, depending upon the launch vehicle. Marine traffic is monitored and plot boards are prepared which show the permissible ship and boat locations and density to assure that the probability of impact on a ship or boat is less than $1x10^{-5}$. Should failure and impact occur beyond the cleared shipping areas (b.2), studies have shown that shipping densities are such that the impact probabilities in the broad ocean areas are low and the probability of an impact is less than $1x10^{-5}$.

Should the vehicle deviate from the flight path (3), the deviation can be in any direction. For WTR launches, approximately 50% of such failures would remain over the broad ocean areas and approximately 50% would be distributed toward populated areas protected by Impact Limit Lines (Event #4). For those not deviating toward public areas, the outcome, (b.2), would result in little public risk whether or not destruct action is taken.

Launch vehicles that deviate toward public areas protected by Impact Limit Lines will be destroyed by the Range Safety Officer, unless a FTS failure occurs (Event #5). Shown previously, the estimate of reliability for the FTS is >0.9994 for redundant systems as utilized on the commercial launch vehicles and the probability of FTS failure is $<6 \times 10^{-4}$. If the FTS operates properly, all debris is contained inside the ILL and the public risks are essentially the same as result (b.2). As shown, the probability of public exposure near the launch area resulting from these failure events, including FTS failure, is $\sim 1.13 \times 10^{-6}$. The public risks resulting from this sequence of events will be examined in a later section; however, with an exposure probability this low, the resulting (d.1) casualty expectancy (Ec) will be less than 10^{-6} in all but a most unusual circumstance.

Launch vehicle failures occurring after 60 seconds in flight may fail over the broad ocean areas being crossed (Event #6) and follow Events #7-#8. The principal difference for failures occurring in this event sequence is that the conditional probability of reaching land is significantly lower (Event #8) and decreases rapidly with time of flight.

d. Launch Vehicle Hazards

The hazards to persons and property are a function of the debris generated by each launch vehicle. Launch vehicle debris hazards vary as a function of destruct action, vehicle failure modes and time in flight of the occurrence. Debris is normally classified by ballistic coefficient, area, weight and number of pieces per category. Debris characteristics for several of the proposed commercial launch vehicles are shown in **Table 14**$_8$ below:

TABLE 14. TYPICAL ELV DEBRIS CHARACTERISTICS

Launch Vehicle	Number Fragments	Lethal Areas (ft^2.)
<u>Delta</u> Launch Phase	320	11,320
<u>Atlas E/F</u> Launch Phase	3,500	15,385*
<u>Scout</u> Launch Phase	1,420	5,851*
<u>Titan</u> Launch Phase	837#	19,787

Note:
* - Estimated lethal area
\# - Actual observed in Titan 34D9 Accident > 2,000 fragments

The debris pattern produced by destruct action or by a launch vehicle explosion varies as a function of induced velocity, ballistic coefficient, altitude of the event and wind drift effects. The impact envelope of these debris are on the order of 1 square mile early in launch and may grow to an area of 25 to 50 square miles later in flight. The effect of the on-shore prevailing winds experienced at the WTR is the major contributing factor to the long and narrow debris pattern. Embedded within this envelope are the fragments shown in **Table 14** above. The fragments are assigned lethal areas which are larger than the actual area of the fragment to account for the fact that injuries to persons can be generated by the edge of a fragment or by a swept area during wind drift.

e. Launch Area Public Risk Assessment

(1) General - The risk of a launch area off-range impact of debris

from typical ELV's has been conducted at the WSMC, using the LARA program. Such studies were performed even though the FTS was assumed to provide absolute public protection. The following assessment provides a gross (but conservative) estimate of the public risk for ELV launches from the WSMC. The mathematical models necessary to perform a more detailed safety analysis for ELV launches that fail and have a subsequent FTS failure do not exist. RTI has computed several estimates of the worst case risks, i.e., ESMC and WFF, however, without sophisticated math models, these estimates cannot be fully verified.

An abnormal ELV that does not break up on the flight path has the potential for exposing the public to impact and debris hazards for thousands of miles in any direction should the FTS fail. The probability of public exposure, however, decreases as a function of the square of the range from the launch point. Hence, the probability of impact at 10 miles is 100 times greater than the probability at 100 miles and 10,000 times greater than an impact at 1,000 miles. Hence, if the probability of impact at 10 miles is 10^{-3}, the probability at 100 miles is 10^{-5} and at 1,000 miles is 10^{-7}.

(2) Failure Modes - Three potential vehicle failure modes which could adversely affect public safety are discussed in the following paragraphs:

- One of the vehicle failure modes which could expose the public to impact of vehicle components is the failure of the vehicle to program downrange; that is, not to pitch over. This will result in a "straight up" ELV. As the missile gains altitude, the debris pattern increases in magnitude, thus causing a potential for endangering the public domain. For a Titan vehicle at the WTR, the impact of the burned out solid rocket boosters (if the flight termination system failed also) would normally be expected to occur east of the launch complex, predicated on wind drift. The lethal area of the solid rocket boosters would be approximately 1400 square feet (700 square feet per booster) which is significantly less than the overall vehicle average lethal area of approximately 20,000 square feet. This would result in the boosters impacting relatively close to the launch site. The other stages (1, 2 and upper stage) would be expected to impact west of the launch site due to the earth's rotation. RTI considers this failure mode as a relatively low risk to the public sector.
- Potential impacts in public areas could also result from a vehicle that is launched in the wrong direction due to an improper roll maneuver of the vehicle during vertical rise. This failure mode, although considered highly unlikely, could be very hazardous to the public domain. Overflight of public areas would be possible without an FTS and the resulting impact of jettisoned stages could create the potential for damage, injury and loss of life. However, RTI considers this failure mode a

relatively low risk due to the magnitude of the guidance errors necessary for this particular failure and the presence of an FTS.

• A failure mode that may have more potential for public exposures near the launch site would be a shift or loss of the inertial reference. This could result in a non-gravity turn trajectory in any direction and subsequent launch vehicle break-up and self destruction due to severe angle-of-attack air loads. This type of failure would tend to scatter debris over a large area at relatively short ranges ,i.e., <20 nm. from the launch site if not prevented by an FTS. RTI also considers this failure mode as a low risk to the public, however, a higher risk than the other examples.

The three examples stated above were presented as an introduction and an aid to provide a clearer understanding of the worst case launch area risk example provided later in this section (paragraph 6).

(3) Population Density - The population density for the local area surrounding Vandenberg AFB is shown by **Figure 26**.[28] This figure illustrates the 1988 population centers and estimated densities within 20 miles of the planned commercial launch sites. The maximum population densities are typically between 2000 and 5000 persons per square mile.

(4) Casualty Expectation - The normal risk measure utilized for judging public risk from the launch of launch vehicles is called Casualty Expectation (Ec). This term is the product of the probability of a public exposure from launch vehicle debris and the total public population exposed to the debris hazard. The equation most commonly used is expressed as:

$$Ec = P_i \times LA \times P_D$$

where P_i is probability of debris impact in a specific public area, LA is the lethal area of the debris impacting in that public area and P_D is the weighted population density for the exposed area defined. The probability of impact (P_i) in the general public areas near the launch site is approximately 1.13×10^{-6} based on the event tree shown in **Figure 25,** page 74.

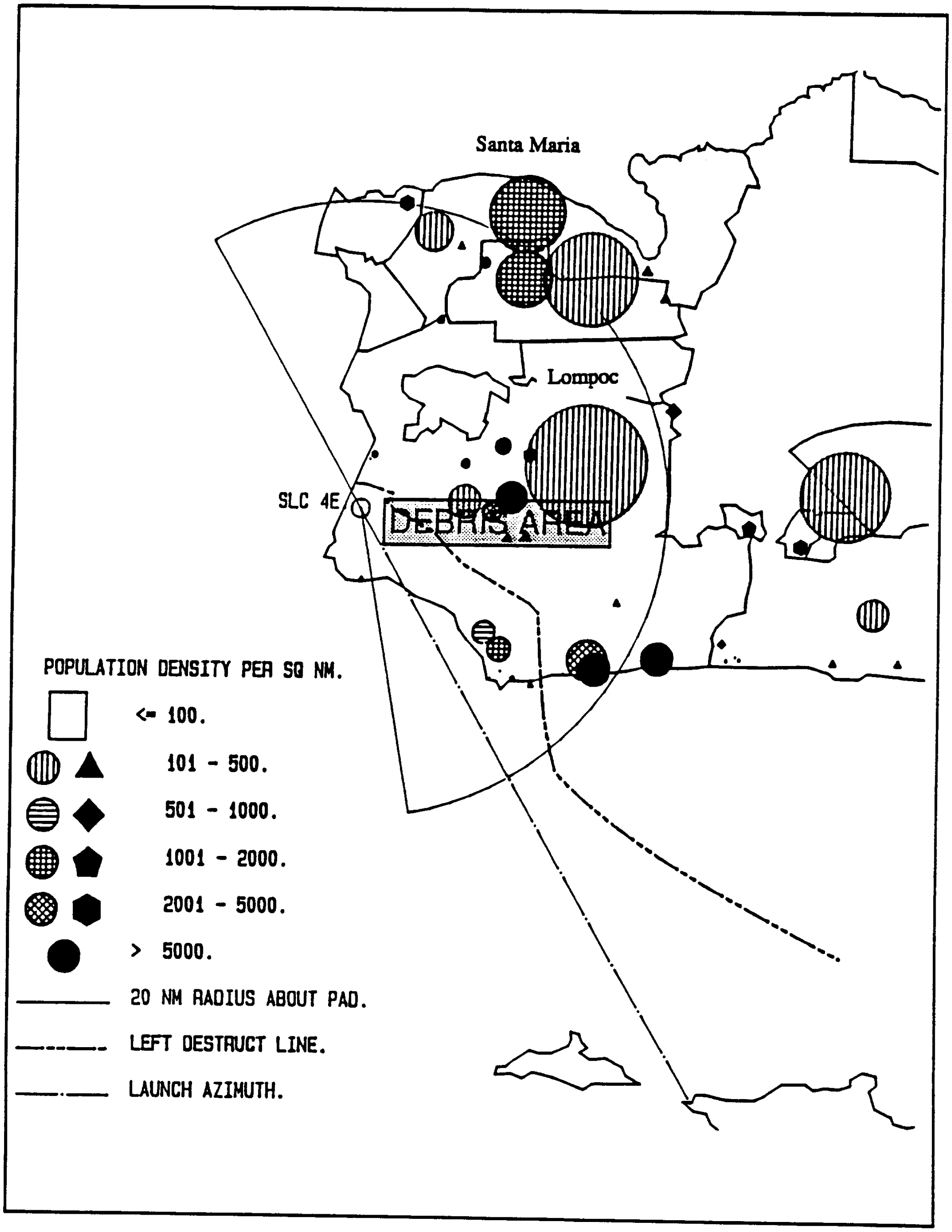

FIGURE 26. VANDENBERG POPULATION DENSITIES

(5) Fragment Debris - The Titan launch vehicle poses the largest fragment debris hazard of the

current ELV's. From **Table 14** above, it was shown that a Titan, during launch phase, will produc e an estimated 837 fragments and a lethal area of 19,787 sq.ft. Approximately 2,000 fragments w ere observed in the Titan 34D9 accident and, therefore, a conservative estimate of the lethal area is; 19,787x2000/837 = 47,280 sq. ft.

As an example of the launch area risks, it is assumed that between 837 and 2000 fragments are generated in a Titan accident at an altitude and velocity that produce a fragment hazard area of approximately 3 miles (cross-range diameter) by 14 miles (in length) at a threat range of less than 20 miles.

A typical debris area for an impact at ranges less than 20 miles is shown in **Figure 26.**[8] The area of a circle 20 miles in radius is 1,256 sq. miles of which 50% or 658 sq. miles corresponds with the off range events from **Figure 25**. An estimated Titan debris area with dimensions of 3 by 14 miles is equal to ~42 sq. miles. Since the debris can impact in only one 42 sq. mile area for any given failure, the average P_i for the region is equal to: $(1.13\times10^{-6})\times(42/658) = 7.2\times10^{-8}$. A worst case estimate of the casualty expectancy, E_c, can be determined by assuming that all the population in the region is concentrated in one 42 square mile debris area. On this basis:

$P_i = 7.2\text{x}10^{-8}$ for any debris impact area within 20 miles

LA = is between 19,787 and 47,280 sq. ft.

P_D = 5000 persons/sq. mi. (Total Pop: 5000x42=210,000 persons)

$E_c = 7.2\text{x}10^{-8}$ x (19,787-47,280) x $210{,}000/42\text{x}6080^2$

$E_c = 1.9\text{x}10^{-7}$ to $4.6\text{x}10^{-7}$

Therefore, the estimated E_c should lie between the values of approximately $1.9\text{x}10^{-7}$ and $4.6\text{x}10^{-7}$ for any off-range impact in populated areas of this region.

An impact in populated areas is very unlikely because the probability of impact includes the probability of FTS failure; however, should it occur, 4 to 10 casualties could be expected based on the E_c assumptions above.

(6) Down Range Public Risks - These risks have not been computed for this assessment. Since the risks are substantially less than the launch area, their contribution is insignificant.

(7) Overflight Hazards - For space missions flown from the WTR, the down range overflight risks do not have a major effect on the overall risk assessment. Space vehicle down range trajectories do not normally overfly populated areas prior to obtaining an orbital state. Even in the extreme cases where overflight occurs (some Atlas vehicles overfly the southern tip of South America) the resulting risks, when based on the dwell time (less than 2 seconds) and sparse population densities (less than 25 persons/sq. mi.), are also insignificant.